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GOVERNMENT PRINTING OFFICE
1885

UNITED STATES GEOL

J. W. POWELL, I

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KEWEENAW POINT,

BY

R. D. IRVING and T.

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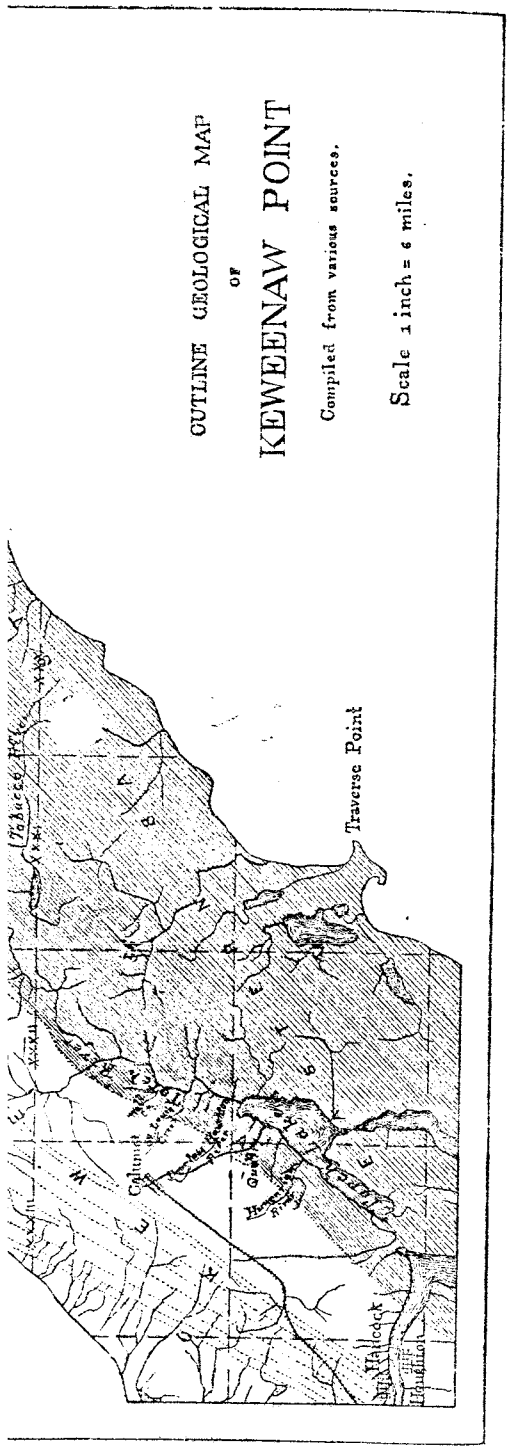

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL DIRECTOR

OBSERVATIONS

ON THE

JUNCTION BETWEEN THE EASTERN SANDSTONE

AND THE

KEWEENAW SERIES

ON

KEWEENAW POINT, LAKE SUPERIOR

BY

E. D. IRVING and T. C. CHAMBERLIN

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Hon. J. W. POWELL,
Director United States Geologic

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UNITED STATES GEOLOGICAL SURVEY,
Madison, Wis., February 15, 1885.

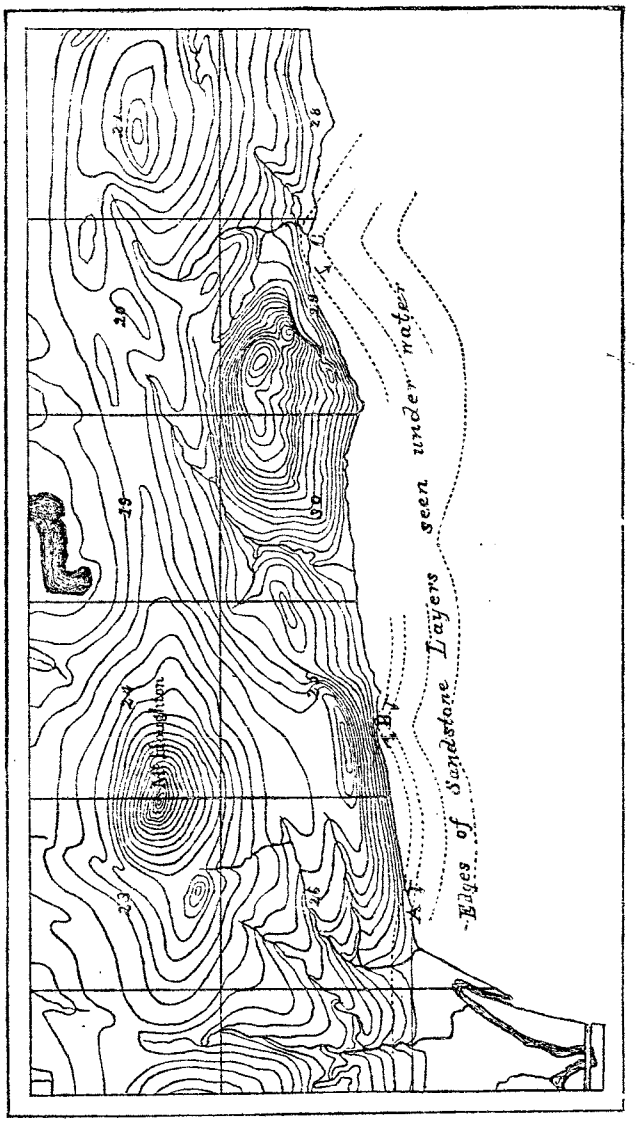
SIR: I have the honor to transmit herewith for publication as a Bulletin of the Survey a paper embodying the results of certain studies in Keweenaw Point geology made conjointly by Professor T. C. Chamberlin and myself.

The accompanying plates, except so far as they are reproductions of photographs, were drawn by Assistant Geologist W. N. Merriam.

I am, sir, very respectfully, yours,

R. D. IRVING,
United States Geologist.

HON. J. W. POWELL,
Director United States Geological Survey, Washington, D. C.



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By R. D. IRVING and

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1880, Part I, pp. 1–25. (R. D. I.)
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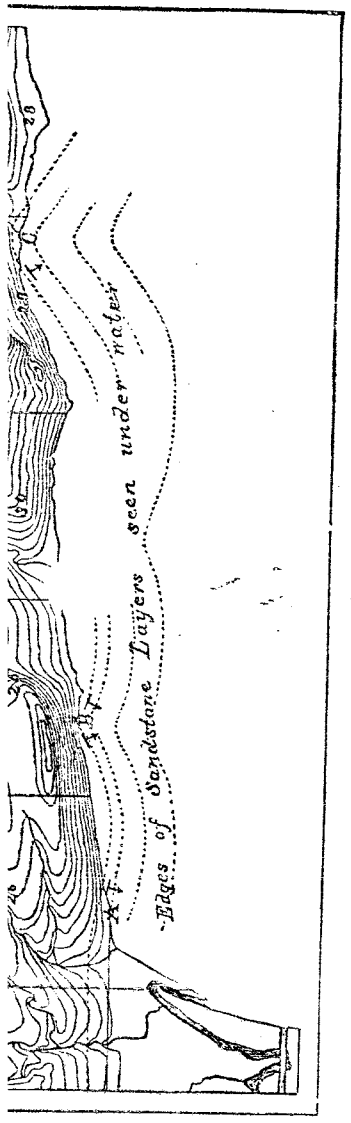

THE JUNCTION BETWEEN THE EASTERN SANDSTONE AND THE KEWEENAW SERIES.

By R. D. IRVING and T. C. CHAMBERLIN.

I.—LOCAL DESCRIPTIONS.

INTRODUCTORY.

Although the copper-bearing rocks of Lake Superior and the adjoining formations have attracted the attention of geologists for fifty years past, there are yet remaining unsolved very many problems with regard to them. We have ourselves, indeed, written at some length with regard to these rocks, and one of us has even attempted a general account of the series as a whole.[1] In the course of our investigations each of us has been obliged to turn away from very many tempting problems in structure and genesis, where there was every promise of successful solutions if only the element of time had not been lacking. Not the least important among the problems which we have hitherto been thus

[1] On some Points in the Geology of Northern Wisconsin. Transactions Wisconsin Academy of Sciences, 1873-'74, Vol. II, pp. 107-119. (R. D. I.)

On the Age of the Copper-Bearing Rocks of Lake Superior and on the Westward Continuation of the Lake Superior Synclinal. American Journal of Science, 1874, Vol. VIII, pp. 46-56. (R. D. I.)

Note on the Age of the Crystalline Rocks of Wisconsin. American Journal of Science, 1877, Third Series, Vol. XIII, pp. 307-309. (R. D. I.)

Note on the Stratigraphy of the Huronian Series of Northern Wisconsin; and on the Equivalency of the Huronian of the Marquette and Penokee Districts. American Journal of Science, 1879, Third Series, Vol. XVII, pp. 393-398. (R. D. I.)

The Geology of the Upper Saint Croix District. Geology of Wisconsin, Vol. III, Part VI, 1880, pp. 363-428. (T. C. C. and Moses Strong.)

General Geology of the Lake Superior Region. Geology of Wisconsin, Vol. III, 1880, Part I, pp. 1-25. (R. D. I.)

Geology of the Eastern Lake Superior District. Geology of Wisconsin, Vol. III, Part III, 1880, pp. 51-238. (R. D. I.)

The Keweenawan Period. Geology of Wisconsin, Vol. I, 1883, Chap. VI, pp. 96-118. (T. C. C.)

The Copper-Bearing Series of Lake Superior. Science, Vol. I, 1883, pp. 453-455. (T. C. C.)

Copper-Bearing Rocks of Lake Superior. Monographs United States Geological Survey, Vol. V, 1883. (R. D. I.)

obliged to pass by is that of the exact nature of the structural details at the contact line between the Keweenaw Series and the so-called Eastern Sandstone. This contact line one of us had already examined sufficiently to satisfy himself of the general relations of the two formations concerned, but he had not been able to go further than this. Recently, however, the opportunity has offered for us to make together some additional observations on this line of contact, with results that have proved to be of so conclusive a nature that we think it well to publish them in the form of a bulletin.

In what follows the several places at which this junction has been studied by us are taken up in order from east to west. Preceding our own descriptions of each one of these points, we give the descriptions of others, so far as we are acquainted with them. Following these detailed descriptions, we then give an account and a discussion of the various views which have been held with regard to the relations of the two formations concerned, and then close with our own conclusions on this subject, as also in general upon the origin of the phenomena observed along the contact line.

BÊTE GRISE BAY.

As often described heretofore, Keweenaw Point consists of two portions, sharply separated topographically: an elevated ridgy portion, and a low-lying flat portion. The course of the ridge portion, beginning at Portage Lake, is at first northeastward; but, as it is followed farther eastward, this course is soon changed into an easterly one, and this again, at the easternmost extremity, into a southeasterly one. To the south and southeast of this crescentic ridge, which is made up of the beds of the Keweenaw Series, lies the relatively low and flat expanse underlain by the Eastern Sandstone. The junction line between these two formations is usually plainly marked in the topography. This is particularly the case towards the northeast, in the vicinity of Gratiot Lake, Lac la Belle and Bête Grise Bay. In the neighborhood of Torch Lake and Torch River the descent from the ridge to the lowland is less abrupt. The relative positions of these two portions of Keweenaw Point and the course of the junction-line of the two formations which underlie them respectively will be best understood from the outline map of Plate I, which is reduced from the colored map compiled from various sources and published in Volume V of the Monographs of the United States Geological Survey.

An inspection of this map will show that, at the eastern end of Keweenaw Point, the ridgy portion occupied by the Keweenaw Series extends some twelve miles farther east than the lowland portion. The rectangular bay thus formed where the lowland terminates is known as Bête Grise Bay. The northern shore of this bay, for some four miles eastward from its western extremity, lies very close to the junction

between the Eastern Sandstone and the

U S GEOLOGICAL SURVEY BULLETIN NO 23 PL III

JUNCTION OF EASTERN SANDSTONE AND KEWEENAWAN MELAPHYR BÊTE GRISE BAY, KEWEENAW POINT

[From a photograph.]

between the Eastern Sandstone and the Keweenawan rocks, being at times slightly to the north and again a short distance to the south of this junction. The topography of the neighborhood of this portion of the bay is indicated on Plate II, which is based upon a tracing furnished by the United States Lake Survey, from a manuscript map in their office. The contour lines stand at 30 feet vertical distance.

On account of their easy accessibility by boat, and also because of the appearances presented, the exposures of the Keweenawan traps and the Eastern Sandstone about this bay have attracted the attention of geologists from quite an early date. The following quotations include all the direct references to this place, as far as the Eastern Sandstone is concerned, that we have been able to gather, after having looked through most of the works in which any such references could be expected. So far as we have been able, we have arranged these quotations in the order of the times when the examinations were made upon which they are based. It has not, however, always been possible to ascertain the exact date from the publications cited. The name which precedes each quotation is that of the author; the date immediately following is that at which the examination was made; after which are given the titles of the works and their dates of publication.

C. T. Jackson, 1848. (Report on the Geological and Mineralogical Survey of the Mineral Lands of the United States in Michigan. Senate Documents, Thirty-first Congress, first session, 1849, Vol. 3, No. 1, p. 442.) "We visited next the mouth of Little Montreal river, and examined the rocks for some distance up that stream. This river falls into the lake over ledges of trap rocks, by a succession of leaps—the aggregate height of these falls being about 40 feet. Further up the stream, there are other minor falls and rapids. The rocks are hard and compact trap rocks, but slightly vesicular. No copper veins are found at this place, or any mineral of interest.

"Continuing our voyage to Lac la Belle, we noticed a peculiar breccia of porphyry and trap rock, which, at first sight, would be mistaken for conglomerate rock. It contains a large mixture of seams of leonhardite, some of which is of a bright red color, from peroxide of iron. Further towards Lac la Belle, we came to nearly vertical strata of sandstone, the dip being NE. 85°. The range of the outcrop, according to Mr. Foster's observation with a prismatic compass, is N. 70° W."[1]

C. T. Jackson, 1848. (Report on the Geological and Mineralogical Survey of the Mineral Lands of the United States in Michigan. Senate Documents, Thirty-first Congress, first session, 1849, Vol. 3, No. 1, p. 451.) "September 5. Rowed against a strong head wind to Jasper point, where we were forced to land on account of the violence of the wind and swell of the lake. Observed at this place (near Jasper point) a dike of brown trap rock, cutting through the porphyritic variety, and thus proving the more recent origin of the brown trap, as I had previously ascertained at other places.

"The wind abating, we set out again in the afternoon and ran round the curve of the bay to near the entrance of Lac la Belle, and then stood for Keweenaw bay,

[1] We are not certain whether this refers to the easternmost of the three places at which the sandstone is exposed on the coast of Bête Grise Bay, which we did not reach (the one marked C on the map of Plate II), or to the middle one (marked B). The latter we have examined, as indicated beyond, but saw no such northerly dip as 85°. However this may be, there is certainly no place where such a bearing and dip hold for any distance, and we doubt its occurrence at any point.

leaving the other boat to visit Lac la Belle. * * * In following the course of the lake near Lac la Belle, I examined the rocks very particularly at their points of junction. The gray sandstone is observed in large blocks suitable for building, though not very compact or strong. The strata in place dip southeast 20°.[1] At the junction of this rock with the trap, and for half a mile north, the rock is brecciated, and a large castle-like outline [outlier] projects into the lake, so that we could run behind it in our boat. The belt of trap in the rear of this breccia is only 40 feet wide. The breccia is seen near the landing of the Clinton Company. During a short stop at the Clinton Company's wharf, I took an observation for time, and then set out on our voyage again. A band of trap a quarter of a mile wide was seen between the breccia and gray sandstone. A curious crescentic band of white sandstone was seen in this bay, beneath the water, and about half a mile from the shore. After passing a band of trap we came again to red sandstone strata, dipping to the south 30°.[2] Point Isabelle is a variegated sandstone cliff, consisting of alternate layers of red, gray, and mottled sandstone in nearly horizontal strata. Orbicular white spots, with nuclei of black, occur abundantly in the red sandstone, and appear to be concretions. Nodules and beds of red chalk are abundant in the gray sandstone or between their strata. This cliff is very beautiful, the top being gray sandstone, the middle red, and the base striped alternately with gray and red. The cliff is perpendicular, affording no landing place: its height is 40 feet. The whole of this sandstone coast is abruptly precipitous, and it is dangerous for boats to be caught by high winds on such a lee shore. The wind was in such a direction that I was enabled to sail quite near the rocks on the wind, so as to observe them leisurely as we ran along the coast."

J. W. Foster, 1848. (Letter to Dr. C. T. Jackson, United States Geologist, dated mouth of Menomonie River, September 28, 1848. Senate Documents, Thirtieth Congress, second session, 1848, Vol. 2, No. 2, p. 160.) "At Bête-du-Gris Bay, where the Bohemian range approaches the lake, we found that the trap, instead of being forced through the layer of sandstone, as observed in the northern slope of Keweenaw point, was protruded through a fissure in the sandstone, tilting it up and causing an anticlinal axis. The bearing of the stratified rocks here is found to be northeast, and the dip 76° to the southeast. A few miles further south the rock becomes nearly horizontal, and between that point and L'Ance it acquires a series of gentle undulations, so that little importance was attached to any of our observations, as to its bearing and inclination."[3]

J. W. Foster, 1848. (Letter to Dr. C. T. Jackson, United States Geologist, dated August 25, 1849, Senate Documents, Thirty-first Congress, first session, 1849, Vol. 3, No. 1, p. 767.) "Two miles above Sibley's landing, sandstone composed of white and red bands is observed, dipping easterly $< 85°$. In the bottom of the bay it is exposed admirably, and can be examined to advantage when the water is calm. It exhibits a series of curves, conforming apparently to the Bohemian range. I was exceedingly anxious to trace out the bearings of these curves, but the party would not submit to the detention."[4]

J. W. Foster, 1849. (Report to Dr. C. T. Jackson, United States Geologist, Senate Documents, Thirty-first Congress, first session, 1849, Vol. 3, No. 1, p. 782.) "On the south side of Keweenaw Point (section 27, township 58, range 28, near the meander-

[1] We take this to refer to sandstone exposure C of Plate II.

[2] We take this to refer to exposure A of Plate II.

[3] We understand this to be a general account of the conditions on the north side of Bête Grise Bay, rather than a reference to any one locality. Certainly, however, the bearing of the sandstone to the northeast and a dip of 76° southeast are not general conditions, but purely local ones, holding at most for a few feet only, since the sandstone, as shown later, presents many different bearings and dips along the contact.

[4] This evidently refers to the same place as described by Jackson in a preceding quotation.

post between sections 27 and 28), above B
bearing N. 22½° E., and dipping southerly
nearly three-fourths of a mile. It is white
nearly so of iron.[1]

"On section 36, township 58, range 29, it
the sixth of a mile, abutting against a bed
E., dip 76° SE.°.[2]

"This conglomerate band, about twenty-
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The same is seen on the Lac la Belle locatio
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"In the bottom of the bay, at this point,
bands can be seen describing immense cu
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geological interest, inasmuch as it enables
and of the bedded trap and conglomerate.

"On the east side of section 14, township
forming the southern shore of Bête du Gris
from the trap, it is nearly horizontal. Th
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colored clay and red ocher, hydrous peroxid

J. W. Foster and J. D. Whitney, 1848–'49.
of the Lake Superior Land District. Par
House Documents, No. 69, Thirty-first Co
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post between sections 27 and 28), above Bête du Gris Bay, sandstone is to be seen, bearing N. 22½° E., and dipping southerly, or away from the trap, for a distance of nearly three-fourths of a mile. It is white and granular, destitute of pebbles, and nearly so of iron.[1]

"On section 36, township 58, range 29, it is again seen on the shore of the lake for the sixth of a mile, abutting against a bed of brick-red conglomerate. Course N. 45° E., dip 76° SE.°[2]

"This conglomerate band, about twenty-five feet thick, is identical in lithological characters with those on the northern slope of the axis, and laps on the chlorite rock. The same is seen on the Lac la Belle location, but beyond that point we have not been able to trace it. The sandstone here consists of alternating bands of red and yellowish silex, with no trace of lime.

"In the bottom of the bay, at this point, when the water is calm, the buff and red bands can be seen describing immense curves, parallel to the direction of the Bohemian range of mountains, and affording conclusive evidence that their bearing and upheaval are due to the protrusion of the igneous rocks.[3] This is a point of great geological interest, inasmuch as it enables us to fix the relative age of the trap range and of the bedded trap and conglomerate.

"On the east side of section 14, township 59, range 29, the sandstone is again seen, forming the southern shore of Bête du Gris Bay. Although removed but a few miles from the trap, it is nearly horizontal. The rock is very fissile, some of the layers yellow or buff, while others are brick-red. It contains numerous concretions of dove-colored clay and red ocher, hydrous peroxide of iron."

J. W. Foster and J. D. Whitney, 1848–'49. (Geology and Topography of a Portion of the Lake Superior Land District. Part I. Copper Lands, Washington, 1850. House Documents, No. 69, Thirty-first Congress, first session, 1850, p. 66.) "The conglomerate, north of the axis of elevation, rarely attains a greater inclination than 45°, but on the southern slope, the sandstone is observed dipping at an angle of 78°. This is beautifully exhibited by the lake shore, on section 35,[4] township 58, range 29. The sandstone is seen in the bottom of the bay, composed of alternating bands of white and red, sweeping round in curves, conformable to the course of the trappean rocks. As we recede a few miles to the south, the strata are observed to be

[1] This we take to refer to sandstone patch C of the map of Plate II. Section 27 should evidently read 29, since there is a long stretch of sandstone on the coast of 28 and 29 (the one described by Rominger, *infra*), and no such patch on the shore of section 27, as stated by Rominger and shown also by the survey-notes to the plat of T. 58, R. 28 W. This error is repeated in several other places in reports by Jackson and Foster and Whitney.

[2] There being no section 36 in this township, there is evidently a misprint here. If "36" should read "26," then this statement refers to the sandstone A of Plate II. But there are no such strike and dip to be observed at A, whilst at the embayment B there is something like it for a short distance. The "36" should then read "25." No "abutment" against brick-red conglomerate was observed here, however, though there is some red conglomerate interleaved with the sandstone, but this conglomerate is in no way like that of "the northern slope," nor is there any "chlorite rock." What with the original vagueness of these descriptions and the numerous misprints characteristic of the Government documents of that time, it is difficult to tell just what is meant in these and other quotations here given from Jackson and from Foster and Whitney. It should be said, however, that it is possible that some of the unaccountable statements by Jackson and others may refer to an exposure of sandstone in addition to those noted on Plate II and not known to us.

[3] And yet these sandstones are crowded with fragments derived from these same igneous rocks.

[4] Again a misprint, since there is no such section in this township.

nearly horizontal. In the two adjoining townships west, this range preserves its distinctive character; but beyond, it sinks down into sloping hills two or three hundred feet in height."

(Ibid., p. 112.) "On the south side of Keweenaw Point, (section 27,[1] township 58, range 28,) above Bête Gris bay, the sandstone is seen bearing north 22½° east, and dipping southeast, or away from the trap, at an angle of 78°, and can be traced along the lake shore for three fourths of a mile. It is nearly white in color, composed almost entirely of silicious particles, and would form an excellent firestone. On section 36, township 58, range 29, it is again exposed, flanking a thin band of conglomerate. It here consists of alternating bands of a white and red color, having a high inclination. In the bottom of the bay, when the lake is tranquil, these bands can be seen describing immense curves, conforming in direction to the course of the Bohemian range. This is a point of much interest, as it enables us to solve the problem of the relative ages of the unbedded and sheet trap and of the associated sandstone and conglomerate. Their order of succession is here distinctly traced.

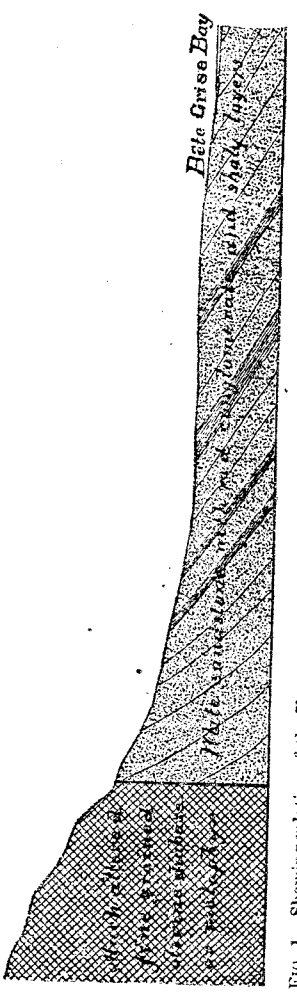

FIG. 1.—Showing relation of the Eastern Sandstone and Keweenawan melaphyr, Bête Grise Bay.

"On the east side of section 14, township 57, range 29, the sandstone is observed in low ledges, forming the southern coast of Bête Gris bay. Although but a few miles removed from the igneous rocks, it reposes in a nearly horizontal position. The rock is very fissile, of a deep-red color, and contains patches of dove-colored clay and ocher, or hydrous peroxide of iron. There are also numerous concretions, resembling, at first sight, the vertebræ or joints of crinoids, the mould being filled with pure white silex, while in the center it is not unusual to see a dark speck corresponding with the alimentary cavity or internal canal."[2]

R. D. Irving, 1880. (Copper-Bearing Rocks of Lake Superior. Monographs United States Geological Survey, Vol. V, Washington, 1883, p. 353.) "The north shore of Bête Grise Bay, as shown on a previous page, is made of low cliffs of Keweenawan diabase and melaphyr, with some quartziferous porphyry, all dipping northward at a high angle; while the west shore of the bay lies in the lowland underlain by the Eastern Sandstone. In the angle of the bay the two formations come together, and their contact may be followed for a long distance. The sandstone, of which a considerable thickness may be seen in continuous exposure, dips southward at angles varying from 55° at the contact to 30° and less at the point farthest removed from the contact. It is made up of alternating whitish, quartzose, fine-grained layers, and thinner ones of red shale; the latter running from a few inches to several feet in thickness. Some of the red layers

[1] Apparently a misprint or mistake again for 29. These statements are plainly repeated from one report to another, the errors continuing throughout. It is singular that when there are such variations in dip and strike at each of the three sandstone localities on the north shore of Bête Grise Bay, single ones, which hold sometimes for a few feet only, should be given in these general statements.

[2] Evidently repeated from Jackson's report, as quoted above.

U. S. GEOLOGICAL SURVEY

PLAT OF EXPOSURES AT JUNCTION OF EASTERN SANDSTONE AND KEWEENAW SERIES, BÊTE GRISE BAY, KEWEENAW POINT.

are strongly conglomeratic, the pebbles being
lar, and composed in the main of red felsite, bu
Keweenawan diabase and melaphyr. The acco
1], representing a length of about 150 feet, is d
contact. The junction line between the sands
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are strongly conglomeratic, the pebbles being generally of small size and often angular, and composed in the main of red felsite, but also in some measure of the ordinary Keweenawan diabase and melaphyr. The accompanying section [reproduced at Fig. 1], representing a length of about 150 feet, is designed to illustrate the nature of this contact. The junction line between the sandstone and the older rocks is quite irregular, and as the shore of the bay is followed eastward, patches of the sandstone are seen remaining in embayments of the older rocks on the cliff side. Underneath the clear waters of the lake the beveled edges of the alternating bands of red and white sandstone may be traced for hundreds of feet in great sweeping curves. On the south point of Bête Grise Bay, below the ship-canal, the sandstone lies horizontally."

(Ibid., p. 184.) "On the north shore of Bête Grise Bay again, in sections 25 and 26, where the contact with the Eastern Sandstone may be seen, the rocks are prevailingly luster-mottled melaphyrs, though much crumbled, altered and seamed with laumontite and calcite. All of these melaphyrs are exceedingly rich in olivine, which, in the thin section, is chiefly represented by a brown or red alteration-product."

In the same work, p. 74, the above-mentioned luster-mottled melaphyr is described as follows, the specimen from which the thin section was taken having been obtained from near the contact with the sandstone, on the southwest quarter of section 27, township 58, range 28 west:

"Microscopic characters: fine-grained, greenish-black, greasy, 'luster-mottled.' Constituents, as determined by microscope, in order of age: *olivine*, very abundant and wholly altered to a green substance, with brown and red stripes, and crowded with the magnetite into the interspaces of the augites; *anorthite*, fresh, tabular, small; *magnetite*; *augite*, in the characteristic areas."

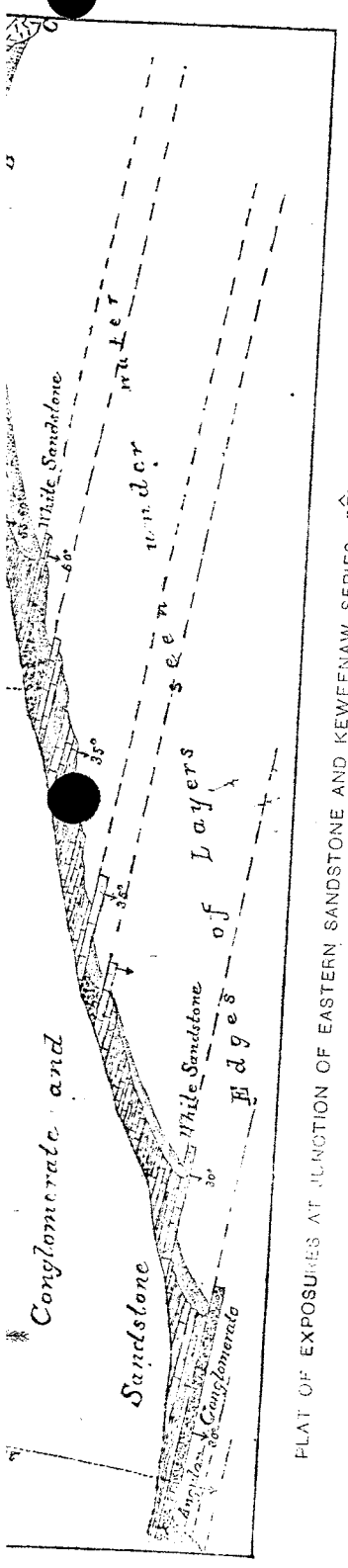
C. Rominger, 1884. (Manuscript notes.) "The best of all exposures showing the unconformable abutment of Silurian sandstones against steeply erected beds of the Copper-Bearing group are seen along the shore of Bête Grise Bay.

"Near the quarter-post of the south line of section 26, township 58, range 29, a succession of light-colored sandstone beds, interstratified with brown-colored, brecciated layers filled with small, angular, but somewhat water-worn fragments of porphyry and of diabase, projects above the water-line, dipping southward away from the land, under an angle of about 35°.[1] Out in the shoal water a continued series of such rock-beds is observable, partly of layers which are ripple-marked. Proceeding eastward along the shore we find these beds in contact with luster-mottled diabase, which dips under a high angle northeastward. The diabase on the line of contact is much shattered, and the net-work of fissures in the rock is replenished with a mixture of calespar and laumonite. The contiguity of the sandstone with the trappean rock, which locally is also an amygdaloid, instead of the luster-mottled kind, can be seen in the lake-bottom for a much greater distance than on the shore.

"Further east another large patch of sandstone occurs on the shore near the center of section 29, township 58, range 28.[2] In the outer portion of this patch the strata dip under an angle of about 20° south, but, following the exposures along the shore eastward, this inclination decreases, and finally, near the spot where the sandstones come in contiguity with the diabase, they are horizontal. The diabase in this locality is likewise the luster-mottled kind, shattered and recemented as in the first locality; the layers show, however, a distinct bedding, and the direction of the dip to the northeast under a high angle is plainly recognizable. The contact of the sandstones with the trap-rock is also from here, for quite a way, traceable in the shoal water. Further east all the shore is formed of diabasic, amygdaloidal and porphyritic rock."

[1] This is the sandstone A of Plate II.

[2] This is the sandstone C of Plate II.



PLAT OF EXPOSURES AT JUNCTION OF EASTERN SANDSTONE AND KEWEENAW SERIES, BÊTE GRISE BAY, KEWEENAW POINT.

The above quotations apply to three distinct exposures of sandstone on the north shore of Bête Grise Bay. Of these three we examined, in October, 1884, the westernmost two, whose positions are shown on the accompanying map of the north shore of Bête Grise Bay, Plate II. Upon the same map we have inserted the easternmost of the three masses, on the authority of Dr. C. Rominger. These three sandstone patches, though separated from one another by long intervals which are occupied by Keweenawan melaphyrs, diabases, etc., as one sees them on the cliff line, are actually in direct continuity with one another underneath the waters of Bête Grise Bay. Here, in calm weather, the water being shallow and exceedingly clear, the connecting masses of sandstone can be followed, and even, as Dr. Rominger has stated in the quotation above given, the junction line between the sandstone and the traps can be traced.

As one follows northward the long sand beach which forms the western margin of the bay, the first rock met with is a reddish, clayey and often shaly sandstone, thickly crowded with dark-colored fragments of the various eruptives of the Keweenaw Series, for the most part quite angular. The angularity of these fragments is exceedingly striking, and is quite convincing as to their nearness to the parent rocks. They run from the size of a pea up to two or three inches, and occasionally even more, in diameter. In the above quoted description of this place, previously published by one of us, these pebbles are spoken of as prevailingly of some of the acid members of the Keweenaw Series, although it is noted that fragments of the basic eruptives are also abundant. On the re-examination, however, the greatly prevailing dark color of the fragments struck us as very noticeable, and on breaking open a number of them we became convinced that pieces of the basic rocks are quite largely predominant, though numbers of them are plainly derived from the usual felsitic and granitic porphyries. Among the basic fragments many derived from the matrices of the ordinary diabases, amygdaloids and pseud-amygdaloids were recognized, as also numerous others derived from the luster-mottled melaphyrs. Although they are often considerably altered, the recognition of the fragments as derived from these eruptives is perfectly simple and easy to any one familiar with the Keweenawan eruptives. Moreover, in a number of instances our recognitions have been confirmed by the study of these fragments in the thin section. This conglomerate layer is in all some four feet thick, but in the middle of this thickness is included an eight-inch seam of red clayey shale, the pebbles disappearing. Above the conglomerate are seen three inches of white quartzose sandstone, one inch of red shale, three feet of fine angular reddish conglomerate, and then other reddish layers which were not closely examined, being covered by the waters of the lake.

Beneath the conglomerate bed first described are three feet in thick-

EASTERN SANDSTONE AND KEWEENAWAN DE ADJYN BÊTE GRISE BAY, KEWEENAW POINT.

[1] See Bulletin No. 6, United

ness of a reddish sandy shale thickly studded with mica scales; and beneath this again a white quartzose sandstone. The thin section of this sandstone showed that while it is composed in great predominance of quartz fragments, many of which, here and there, show secondary enlargements,[1] there is yet contained a quite noticeable proportion of fragments derived directly from the basic members of the Keweenaw Series. Occasionally the fragments are large enough to be seen in the hand specimen with the naked eye. When distinctly recognizable microscopically they are seen to have been chiefly derived from the matrices of some of the amygdaloids, being composed of minute tabular plagioclases imbedded in a non-polarizing red-stained matrix. These fragments are noticeably angular, and in this respect present a striking contrast with the quartz fragments of which the rock is mainly composed.

Beneath this sandstone layer succeeds now a series of alternations entirely similar to those already described; the white sandstones, on account of their greater hardness, frequently projecting towards the lake in such a way as to overhang the little shingle beaches that have been formed behind them. The red shale layers and shaly conglomerates, on the other hand, being soft, have usually washed to a more uniform surface, and, in several instances, they have been found forming the cliffs at the bottoms of little coves, whose sides are made of the layers of harder white quartzose sandstone. These white sandstones contrast very strongly in color with the red shales and conglomerates with which they are interstratified, and, underneath the waters of the lake, the edges of the alternating red and white layers may be traced for long distances in great curving bands. As this succession of layers, which strike S. 80° E. (true), is crossed to the northward, they are found to take steeper angles of dip, the northernmost layers seen reaching 55° and even 60° in southward inclination. Indeed, the increase in dip is often noticeable in individual layers; for instance, in the first white sandstone layer to the southward of the more northerly rocks next to be described. The position of this particular layer is indicated on Plate IV, and is also shown at the left of Plate III, which is taken from a photograph, the direction of outlook being south of west from the point A of the first-named figure.

Immediately to the north of this sandstone layer comes in a belt of very soft red shale and shaly breccia. The position of these red layers is indicated on Plate IV. In the views of Plates III and V they also show in the left center of the picture, extending from the shovel shown lying against the bank as far as the projecting layer of white sandstone above mentioned. Measured along the bank, which here trends north of east, these layers have a width of some twelve paces. They are alternatingly quite soft red shales, containing numerous minute mica scales,

[1] See Bulletin No. 8, United States Geological Survey.

and layers of sharply angular fragments of the various Keweenawan eruptives thickly set in a red shaly matrix. Among these fragments, which in the main are rather smaller than those seen in some of the higher conglomerate or breccia layers, many are recognizable as identical with the altered, luster-mottled melaphyr lying immediately to the north, or, as one follows the course of the bank, to the northeast.

These soft, red layers, and the broken and altered rocks immediately to the north of them, had so crumbled and weathered down that, in order to make out the exact succession here, we were obliged to strip the bank somewhat thoroughly for a distance of some 30 feet. On doing this we found immediately beneath the red layers just described, which essentially form the base of the Eastern Sandstone at this place, about three inches of a red clay resembling what is sometimes found in joints or fault fissures. In this clay, however, are some traces of a lamination according with that of the shales above, so that we did not feel certain as to whether it should be looked upon as a fissure clay or as forming the base of the red layers immediately to the west and south. It seemed to us, indeed, that this clay might belong in some measure to each of these categories; *i. e.*, might be the base of the red shale rubbed into a joint clay by faulting motion. The position of this clay seam is indicated by the shovel in the view of Plates III and V.

Measuring along the bank eastward from the red-clay seam just described, we find a 9-foot face of a breccia, formed of fragments, mainly from one to four inches in maximum dimensions, but occasionally reaching a foot. The greater part of these fragments are similar to the melaphyr seen in the bank immediately to the eastward; but some are compact, dark-colored diabase, similar to a rock that lies along the shore some thirty rods or more to the eastward. Others again are compact, fine-grained and dark brownish, and may in some measure belong to the acid or intermediate rocks of the Keweenaw Series, but on the ground we took them to be mainly of some of the basic kinds. They are all angular or subangular, but for the most part show some blunting of the angles. Between them often lies a reddish clay, like joint clay, that does not appear to form a true matrix, as in the case of the conglomerates farther to the south and west. As the fragments are taken out this clay commonly coats them, and in many cases shows strongly marked, shining, "slickensided" surfaces. This zone of breccia, then, we do not take to be a part of the sandstone series proper, but rather to be a junction débris which has resulted from a faulting motion that has taken place between the sandstone and the trappean series. It seems quite possible that decomposition, which is so common a phenomenon at the contacts of diverse formations and which is so apparent in the adjoining melaphyrs, had prepared the way for the easy production of this débris. In the view shown in Plates III and V

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[1] Metasomatic Development of the Co
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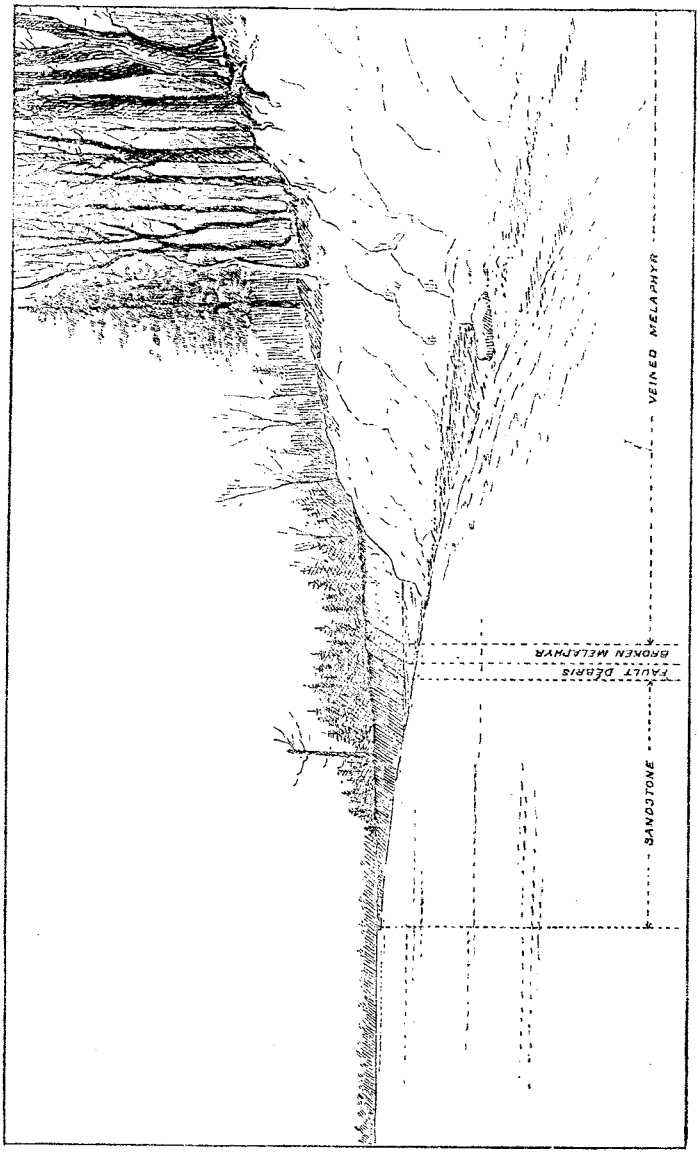


GENERAL OUTLINE VIEW OF THE JUNCTION OF THE EASTERN SANDSTONE AND KEWEENAWAN MELAPHYR, BÊTE GRISE BAY KEWEENAW POINT.

U. S. GEOLOGICAL SURVEY

MONOGRAPH XXIX PL. VI

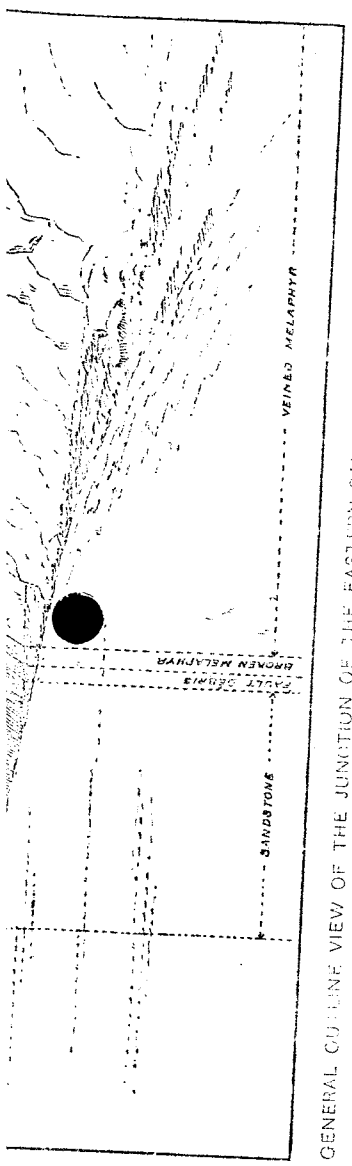
this zone stretches to the right from the shovel to the first pole laid against the bank. Its position is shown on Plates IV and VI.

As indicated on Plate IV, the entire width of the sandstone series here exposed, measured upward from the upper limit of the breccia zone just described and at right angles to the strike, is 230 feet. With an average dip angle of 35° this width corresponds to a thickness of 133 feet.

Next east of the zone of fault débris the bank shows a face of eight feet in width of much-broken, altered and decomposed melaphyr, embracing a considerable proportion of secondary matter, especially chlorite and calcite. The position of this zone is indicated in the several figures already referred to. In the view of Plate III it extends between the two poles seen lying against the bank. It is not separated, however, from the brecciated zone immediately west of it by any definite line; the two grade into one another insensibly. Neither is there any distinct line of demarkation between this zone and the melaphyr, which extends some distance farther eastward.

Following the bank eastward, this melaphyr is found becoming more and more compact, though much veined with laumontite and calcite. At the point B of Plate IV it comes out to the water's edge and forms the bounding cliff of the bay. Here the rock is much fresher, and is seen to be one of the typical luster-mottled melaphyrs of Pumpelly.[1] The luster-mottling is rather small, the rock belonging to one of the finer-grained phases of its class, but is rendered quite apparent on weathered surfaces by the reddish decomposition of the olivine and probably also of interstitial glassy substance. In the thin section the olivine is seen to be peculiarly abundant and in unusually large grains for the size of the luster-mottling. It is wholly altered to a greenish material, which is also often combined with much oxide of iron. The plagioclase, which from the angular measurements appears to be near anorthite, and the augite are both often quite fresh. The usual magnetite is present. The dip of this rock is not satisfactorily seen at this place, inasmuch as for a considerable distance we are dealing with only one great flow. Nevertheless, from the general occurrences elsewhere met with along the Bohemian or southern trap range of Keweenaw Point; from the northern dips which characterize the section immediately to the northward of this as far as Mount Houghton; from the similar northern dips met with within half a mile to the eastward, along the Bête Grise cliffs, where one of us saw in 1880 at least one bed of conglomerate interstratified in the traps; and from the similar northern dips described by Dr. Rominger as obtaining all along the coast to the extremity of Keweenaw Point and along the lower reaches of the Mon-

[1] Metasomatic Development of the Copper-Bearing Rocks of Lake Superior, Proceedings American Academy of Sciences, Vol. XIII, pp. 269–270; Geology of Wisconsin, Vol. III, p. 33; Copper-Bearing Rocks of Lake Superior, Monographs United States Geological Survey, Vol. V, pp. 68–77 and Plate IX.



GENERAL OUTLINE VIEW OF THE JUNCTION OF THE EASTERN SANDSTONE AND KEWEENAWAN MELAPHYR, BÊTE GRISE BAY, KEWEENAW POINT.

treal River—it is believed that the inclination here is at a very high angle to the northward, with the strike to the north of east.[1]

The sketch of Plate VI is a general outline view of the various exposures above described looking south of west from the point C of Plate IV. In the distance is seen the low land immediately behind the long sand beach which forms the western shore of Bête Grise Bay (see Plate II). In the middle distance are shown the alternating sandstones and conglomerates of the Eastern Sandstone dipping southward. Following these towards the foreground, we come upon their junction with the traps at the central point of the sketch. The irregular rocks in the foreground are composed of black melaphyr, and are the same as shown at the extreme right of Plate IV. A photograph was taken showing this same view, but unfortunately when the plate was developed it did not prove to be sufficiently successful for reproduction. The outlines of the view were, however, sufficiently distinct for us to trace from, and in that way we have constructed this sketch.

The second of the three sandstone localities on the north shore of Bête Grise Bay is the one marked B on Plate II. Between it and the

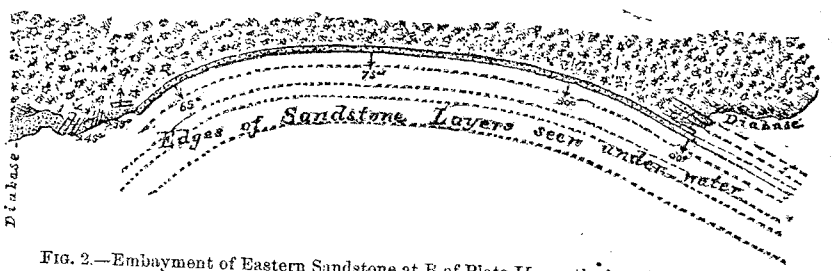


FIG. 2.—Embayment of Eastern Sandstone at B of Plate II; north shore Bête Grise Bay.

sandstone exposures at the northwest angle of the bay, already described, the cliffs are entirely composed of Keweenawan melaphyrs and diabases, which strike in this distance apparently more to the northward than the coast line, and rise very abruptly from the shore-cliffs into heights of more than 500 feet. At the westernmost point of this exposure of sandstone it is found striking N. 39° E., or sharply in shore, and dipping 46° to the southeast, while within a few steps to the westward the Keweenawan diabase is seen. This, then, is the same junction as above described, where the strike of the sandstone was, however, S. 80° E. Between the two places much of the northern edge of the sandstone may be seen beneath the waters of the lake. This northern edge thus forms a great curve, which here reaches the shore again in its course. Continuing our examinations of this sandstone to the eastward, we find the strike gradually changing, until, at 25 paces from the beginning, it is only 9° east of north, with an eastward dip

[1] Copper-Bearing Rocks of Lake Superior, Monographs United States Geological Survey, Vol. V, pp. 179–185; also Plates XVII and XVIII.

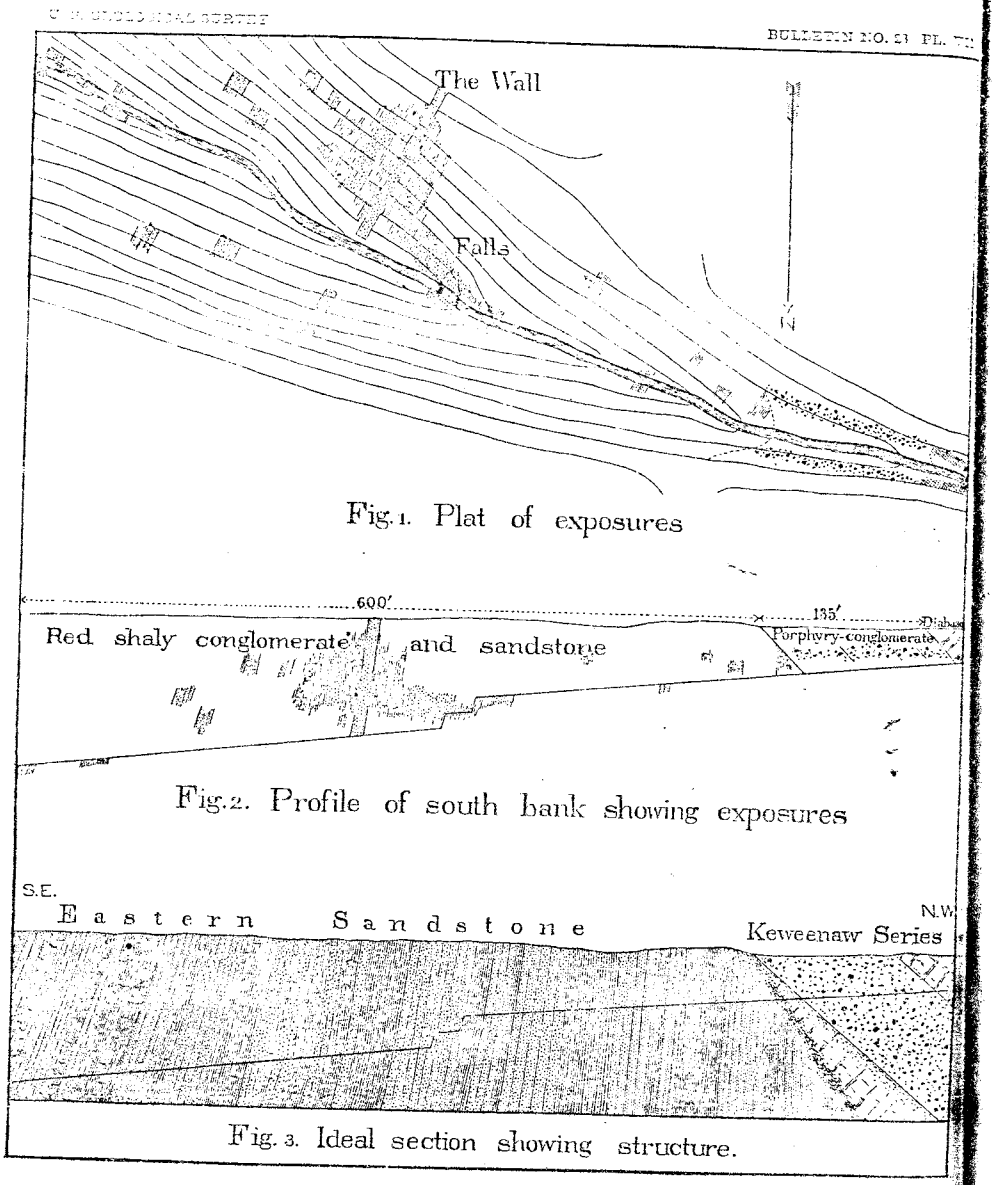


Fig. 1. Plat of exposures

Fig. 2. Profile of south bank showing exposures

Fig. 3. Ideal section showing structure.

JUNCTION OF THE EASTERN SANDSTONE AND THE KEWEENAW SERIES, WALL RAVINE.

Scale: 1 inch = 150 feet.

of 55°. Nine steps further there is
clinal appears in the cliff face, the
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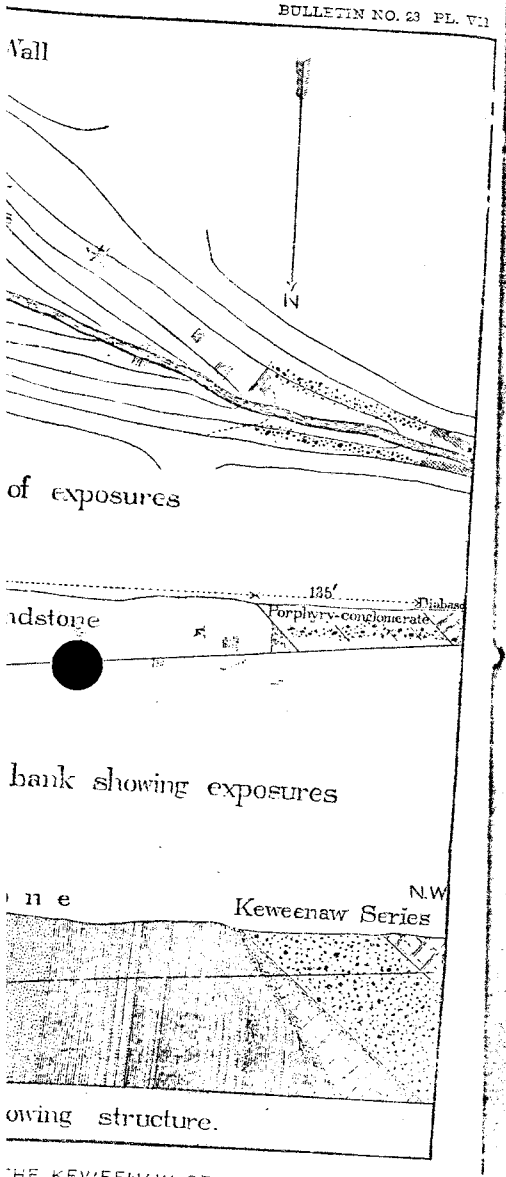


THE KEWEENAW SERIES, WALL RAVINE.
0 feet.

of 55°. Nine steps further there is a sudden overturn, and a little synclinal appears in the cliff face, the dip in the bottom of the synclinal being 24° to the north, and strike N. 79° E. Ten steps further this dip is changed again for one of 65° to 75° to the southeast, and the sandstone layers can be followed in nearly vertical position along the cliff line, which here forms a re-entering curve, corresponding to a similar curvature in the strike of the sandstone layers. As we follow this curving cliff eastward, the dip of course changes gradually to a southerly and again to a southwesterly one, at the same time first increasing to verticality and a few degrees beyond, and then returning to a somewhat flatter dip. Underneath the water in front of the cliff a long succession of similarly curving bands of sandstone may be seen. Finally, at about 20 rods from the beginning, the sandstone leaves the coast again, striking in a southeasterly direction, and the cliff is composed once more of the ordinary Keweenawan eruptives, which rise immediately behind in bold bluffs several hundred feet in height. From the face of the Keweenawan traps the sandstone has in part fallen away, but in part it has adhered to them and the exact contact may be seen. It is noteworthy that the trap at the contact is not now a luster-mottled melaphyr, but is, on the contrary, one of the ordinary diabases of the Keweenaw Series, much altered and more or less fine-grained. The sandstone here is of the same nature as at the first described place, being prevailingly quartzose, interstratified with reddish shaly portions and carrying in some parts many fragments of the underlying rocks. Nevertheless it is evident that the contact here is not at exactly the same horizon of the sandstone series as in the other instance.

To the eastward from this place we know at present of no sandstone on the land except that at the point C of Plate II. Not having examined this point ourselves, we do not attempt to add anything to the statements of Dr. C. Rominger, above quoted. Between these two points, however, the curving edges of the south-dipping sandstone strata may be traced for considerable distances. Possibly they could be followed for the whole distance in calm weather. From the appearances one of us saw along the shore of section 30 from a boat, being unable to land, he suspects that there may be here at least one more embayment of the sandstone like that at B.

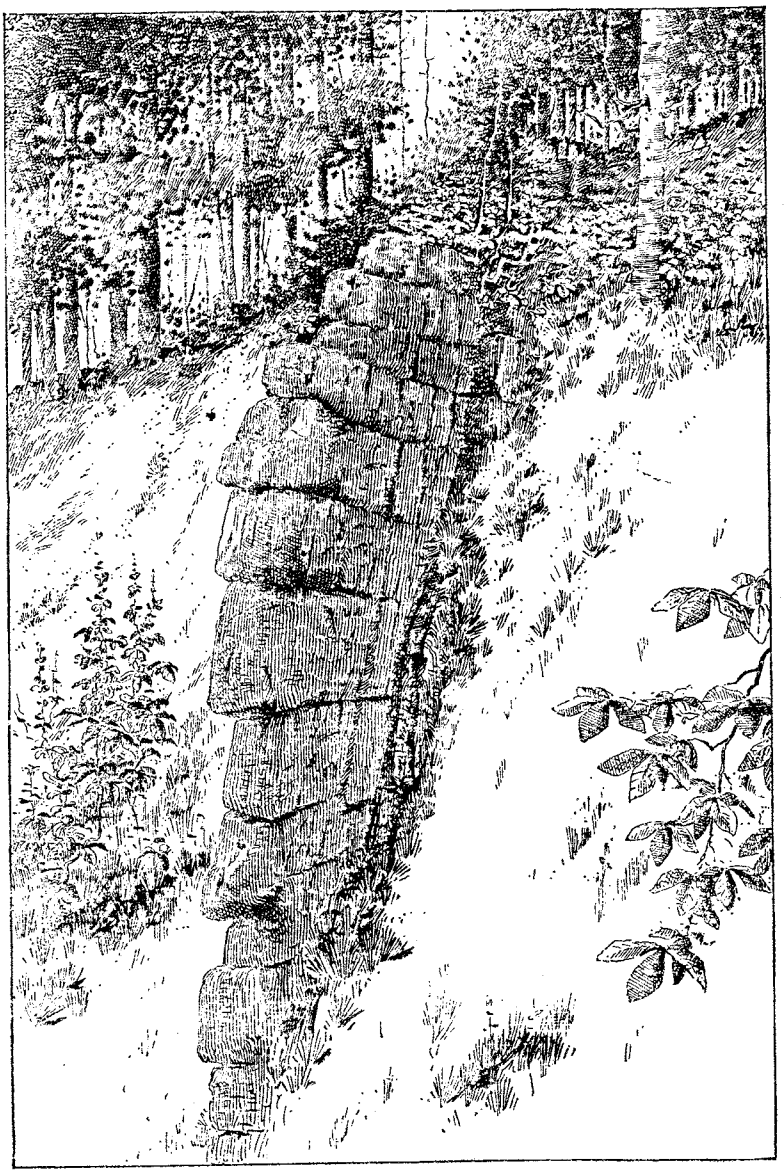
WALL RAVINE.

The ravine to which we have given this name, on account of the somewhat striking natural wall of sandstone extending into it from the south side, lies in the north half of Sec. 20, T. 56, R. 33 W. Our attention was first drawn to this very interesting and important place by Mr. West, chief engineer of the Calumet and Hecla mine. So far as we have been able to learn, no geologist had previously made any ex-

amination of this place; certainly we have met with no reference to it in the various publications with regard to Keweenaw Point geology. The portion of the ravine which was examined by us in detail is indicated in plan on Fig. 1 of Plate VII. At the eastern end of the area there mapped, in the bed and on the sides of the stream, we noted red shale and white quartzose sandstone, dipping down stream, or southeasterly, at an angle of 60° to 65°, the individual layers being seen to curve from the flatter angle below to the steeper one above.

Following now the bed of the stream upwards, we found, at 30 steps from the first exposure, another one of red sandy shale, holding pebbles of various Keweenawan eruptives, basic and acid, exposed in a slide at the foot of the wall of the ravine and also in the bed of the stream. Here the same curvature as before was seen, but the dip is now increased to 75° southeast. Farther up-stream for 75 paces both walls of the ravine show partially covered exposures of red shale and shaly conglomerate, with interstratified seams of harder, white, more purely quartzose sandstone, upon which we did not make any measurements, but all of which, so far as we observed, present the same high dip down-stream.

Much more satisfactory exposures, however, begin at the end of these 75 steps, and continue up-stream for some distance. These exposures are in the south bank of the ravine. First, on a steep bank, where a recent slide has uncovered the rocks, is seen a series of alternating layers of red shale, shaly conglomerate and reddish, purely quartzose sandstone, all inclining to the southeast some 75° to 80°, and resembling closely the alternations already described as met with in the northwest angle of Bête Grise Bay. One point of difference from the Bête Grise succession is to be noted, however. This is the larger size and more perfect roundness of the pebbles of the conglomerate. While these are, to some extent, subangular, they never show the sharp angularity of the Bête Grise pebbles, but, on the other hand, are often unusually well rounded, and range from the size of a pea to bowlders 18 inches in diameter. These pebbles, while all plainly derived from the eruptives of the Keweenaw Series, are less prevailingly from the basic rocks than in the Bête Grise conglomerate, a considerable portion of them having come from the Keweenawan felsites and granitic porphyries. The characteristic diabases and amygdaloids are, however, abundantly represented. While on the ground we saw several good-sized subangular fragments, which we took to be from some of the finer grained Keweenawan porphyry-conglomerates, an observation which would be confirmatory of the very important statement made by Agassiz and Pumpelly as to the occurrence of conglomerate fragments in the Eastern Sandstone at the Douglass Houghton and Saint Louis ravines. The one among these fragments which was brought home proved, however, on closer examination in the hand specimen and thin section, not to be from a conglomerate, but from a granitic porphyry somewhat crumbled from de-



"THE WALL," WALL RAVINE, KEWEENAW POINT. WEST SIDE.
[From a photograph.]

composition. We are unable, therefore, to assert with the positiveness that we could wish that such fragments actually occur, though on the ground we had no doubt of their occurrence.

The land-slide showing these conglomerates, shales, etc., is terminated on the up stream side by a massive layer, some three feet thick, of nearly white, purely quartzose sandstone, which projects from the side of the ravine in a wall some 90 feet in greatest height and 40 feet in greatest projection from the slope. This wall is shown in view on Plates VIII and IX, both of which are from photographs taken by us from the opposite or north side of the ravine, the first named showing the southeast side of the wall, the other its northwest side. The strongly marked horizontal joints, which are shown in the figures and which so greatly increase the resemblance of the rock to artificial masonry, are not bedding planes, but cross joints, the direction of the bedding being that of the wall as a whole. At the foot of the wall its inclination is 78° to the southeastward; half-way up 80°, and, at the top, about 85°; the course of the wall being 26° east of north. The curvature from flatter to steeper dips already noted as seen in certain layers farther down stream is thus further illustrated here. On the opposite side of the ravine the same layer of white sandstone projects in a less strongly marked manner. There is not the least possibility of mistake or erroneous interpretation as to the vertical position of the layer forming the wall and of the entire succession of sandstones and conglomerates. The bands of shale and conglomerate occur on both sides of the wall in concordant attitude with it.

Up-stream from the wall similar vertically placed sandstones, red shales and red shaly conglomerates continue to appear in the bed of the stream, where they produce two small falls, and in the sides of the ravine with some interruption, until, finally, the junction of the sandstone with the undoubted Keweenawan rocks is met with. The latter rocks are represented here, as indicated on the topographical sketch and section of Plate VII, by a characteristic porphyry-conglomerate about 135 feet in width, immediately overlying which are diabase and diabase amygdaloid. The occurrences at the exact junction, upon which we made a considerable excavation with the aid of a force of miners, are shown in the accompanying sketch, page 26.

The conglomerate, which just above on the banks of the stream shows in natural exposures of considerable size, appears in the excavation in a somewhat fissured mass. This mass, however, is evidently essentially *in situ*, since it retains the characteristic northwestern dip of the series in the vicinity. The pebbles of this conglomerate are, for the most part, rather fine, but occasionally reach a considerable size, and are commonly of some of the acid eruptives of the Keweenaw Series, particularly of the felsitic kinds. There is a plentiful mixture, however, of fragments derived from the basic Keweenawan eruptives, this being particularly the case with the smaller fragments. The rock is considerably

indurated, and in the thin section the induration is seen to be due to a plentiful saturation by calcite.

Obliquely beneath the under face of the conglomerate, which did not present the appearance of a definite bedding plane, lie about 15 inches of broken, rounded and crushed rock, imbedded in a dark, reddish-brown clay, which is manifestly of an entirely different nature from the indurated matrix of the conglomerate immediately above it. Next below this clay follows a thick mass of dark shaly material, embracing trap débris and fragments of conglomerate and sand from the Eastern Sandstone. This mass is evidently of the same nature as the material met with at the same junction at Bête Grise Bay, as already described, and on the Douglass Houghton and Hungarian rivers, as subsequently

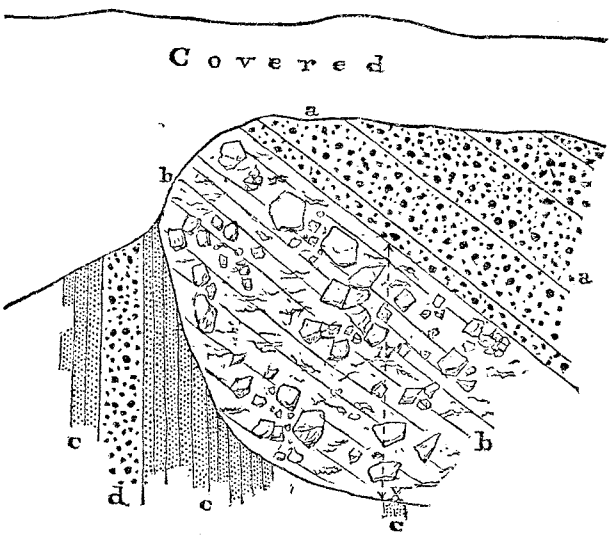
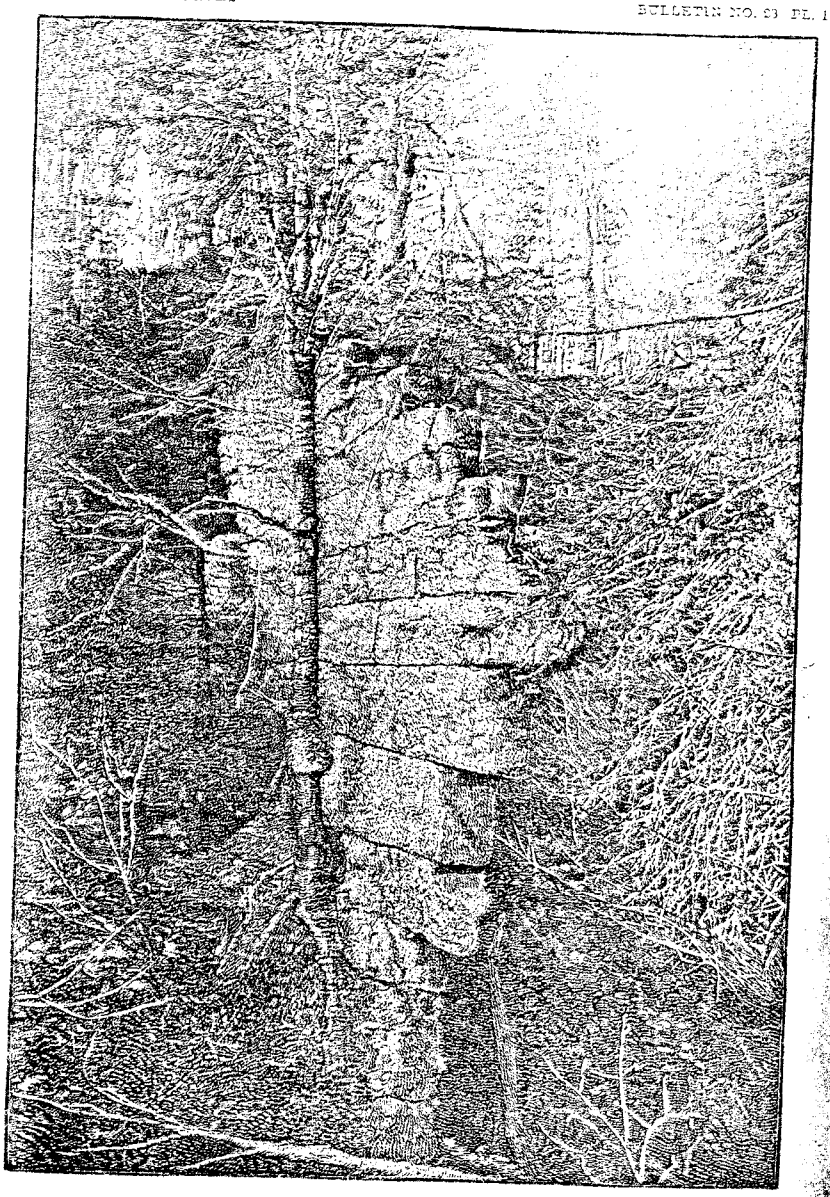


FIG. 3.—Junction of the Eastern Sandstone and Keweenawan porphyry-conglomerate, Wall Ravine, Keweenaw Point. *a a*, Keweenawan porphyry-conglomerate; *b b*, junction débris; *c c c*, vertically placed Eastern Sandstone; *d*, conglomerate layer included in *c*.

described. It is to be noted that this junction formation, which is so manifestly the same at all of these places, is in contact at no two of them with the same horizon of either the Keweenaw Series or the Eastern Sandstone. On the contrary, it is in contact with horizons which must belong many feet apart in the different cases. It is thus manifestly not a stratum of either one of the two formations concerned, but belongs in the space between the two. Measured in the excavation, along a line normal to the Keweenawan conglomerate, beginning at a point about 12 feet below the top of the bank of the ravine, the thickness of this joint material was found to be 10 feet and 4 inches. Measured on a line normal to the sandstone next to be mentioned, the thickness is 14 feet.

Next down stream from the joint material just described, comes the Eastern Sandstone, which is here of the normal quartzose type, being



"THE WALL," WALL RAVINE, KEWEENAW POINT. EAST SIDE
[From a photograph.]

white and friable. In the thin section

white and friable. In the thin section, the rounded particles of this rock are seen to be composed almost wholly of quartz, many of the grains showing slight secondary enlargements. Mingled with the greatly predominant quartz grains are a few of orthoclase and plagioclase and of the matrices of Keweenawan diabasic and felsitic eruptives. Between the grains there is a somewhat plentiful filling material of kaolinic substance and fine quartz, with here and there a flake of muscovite. The junction face between this sandstone and the joint material varies between S. 35° E. and S. 45° E. in bearing, and stands about vertically as seen in the excavation, but the appearance of sandstone at the point X (p. 26) of the sketch, immediately at the base of the excavation, seems to indicate that the face of the sandstone is not plane, but on the contrary that it descends by offsets. The bedding of the sandstone at the junction is approximately vertical, coincident with what is seen farther down the stream, as already described. This is rendered plain, not merely by joints in the sandstone, but by the presence here of one of the layers of coarse pebble conglomerate.

In Figures 1 and 2 of Plate VII we have attempted to show exactly the extent and positions of the exposures actually seen along this ravine as far as we examined it. In Figure 3 of the same plate we give the structure which, as we think, these exposures plainly indicate.

In the distance examined by us below the junction of the sandstone and Keweenaw Series, there is displayed a thickness of sandstone with interstratified shale and conglomerate of little less than 600 feet.

SAINT LOUIS RAVINE.

This ravine begins in Sec. 19, T. 56, R. 32 W., and runs thence through parts of sections 20 and 29 of the same township. The exposures on it examined by us lie in the vicinity of the old Saint Louis mine. The place is easily reached from Calumet by the old road to Torch Lake. The following quotation, from a paper by Mr. Alexander Agassiz, comprises the only published reference to this place that we have met with:

> Foster and Whitney, in their report of the Lake Superior mineral district, represent the sandstone on the south side of the trap range of Keweenaw Point, as dipping south and resting conformably upon the beds of trap of the north side of the anticlinal axis of Keweenaw Point. This anticlinal axis, formed by the Bohemian Mountain, as asserted by Foster and Whitney, is not found farther south, as far as I have had occasion to examine. In two of the ravines cut through the sandstone by creeks flowing in an easterly direction from the crest of the range towards Torch River, near the head of Torch Lake, we find good exposures of the sandstone, and in two points, one of which was examined by Foster and Whitney, we find the sandstone resting unconformably upon the trap which has still the same northern dip as farther west, of about 42°. The sandstone within a distance of 100 feet from the trap, dipping north 42°, lies horizontally, or rather has at the outside an inclination of 1½° or 2° south. The peculiar bed of chloritic rock, so characteristic of the junction of trap and sandstone as described by Foster and Whitney, is well marked, but

we can find no trace whatever of any anticlinal axis at these two ravines, which are about 2 miles apart and present identical features. One of these ravines commences in the property of the St. Louis Mining Company, Section 19, Township 56, Range 32 North, about 1½ miles south of Calumet. An old adit entering from the ravine into an abandoned lode plainly shows that the formation still dips about 42° north. About 600 feet farther east, following the ravine where the dip of the formation does not change, we come upon the bed of chloritic rock forming the junction of sandstone and trap, and about 100 feet farther down the ravine we come upon horizontal beds of sandstone reaching to the very crest of the ravine, here about 100 feet deep, plainly showing that the sandstone rests unconformably upon the trap which has a dip of 42° north. These same horizontal beds can be traced the whole length of the ravine for a distance of over 1½ mile. (On the Position of the Sandstone of the Southern Slope of a portion of Keweenaw Point, Lake Superior. Proceedings of the Boston Society of Natural History, Vol. XI, 1866–1868, pp. 244, 245.)

Fig. 1 of Plate X is a topographical sketch of the portion of this ravine examined by us, based upon pacings and coursings measured with hand compass.

A few steps above the old stamp mill at the Saint Louis mine there is an artificial opening on a bed of porphyry-conglomerate six and a half feet thick, the contacts with the underlying amygdaloid and overlying diabase being both visible. The dip of this conglomerate bed we made by careful measurements to be 47° NW., its bearing N. 36° E. (true). The display here is so entirely satisfactory as to leave no doubt whatever with regard to the general northwesterly dip of the Keweenawan rocks at this place.

Eighty-five steps down stream from this place, on the same bank, at a point between 40 and 50 feet above the bottom of the ravine, the junction with the Eastern Sandstone was found. The sandstone at the junction and its included bed of conglomerate dip here towards or beneath the Keweenawan rocks at an angle of about 70°, striking with the face of the hill, or N. 40° to 42° E. These measurements were made on the junction between the sandstone and an included conglomerate layer, so that no room is left for doubt as to their correctness. The sandstone here is of the usual quartzose type, and both it and the included conglomerate are entirely like those seen at the junction on Wall Creek already described. In the bank above the sandstone the Keweenawan diabase rises in a large exposure some 10 or 15 feet in height. For lack of time we were unable to excavate here sufficiently to uncover the absolute contact of the two formations, but enough was done to carry the diabase to within two feet of the sandstone, and to convince us that the phenomena here are entirely analogous, with one exception, to those met with at the junction on the Wall Creek Ravine.

The exception is the northwesterly dip of the sandstone here displayed at the contact. But this is plainly an overturn dip, and not one indicative of a passage of the entire sandstone series beneath the Keweenawan, for, in the first place, the dip of the sandstone, 70°, does not conform to that of the Keweenawan rocks, 47°; and, in the second place, we find as we pass down-stream from the junction that the dip

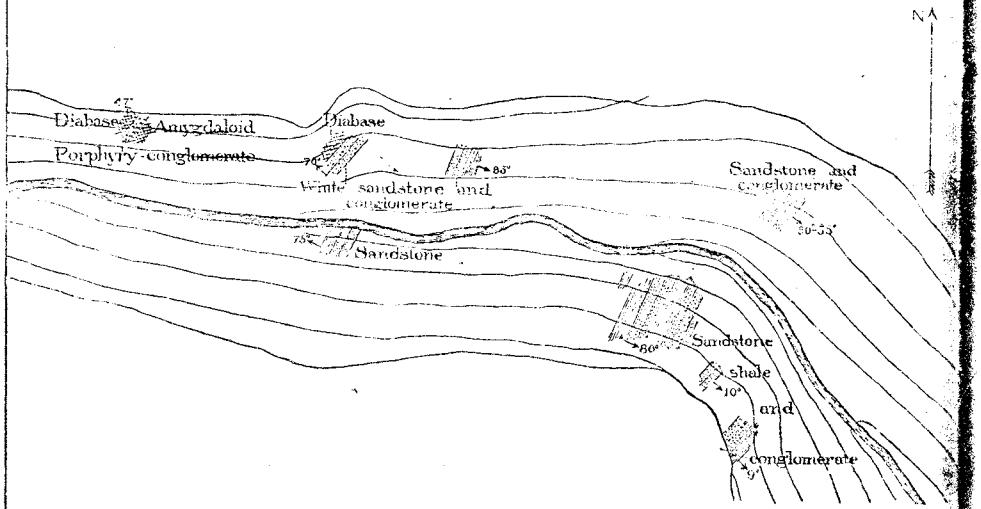


Fig. 1. Plat of Exposure.

Fig. 2. Ideal section showing Structure.

JUNCTION OF THE EASTERN SANDSTONE AND THE KEWEENAW SERIES, ST. LOUIS RAVINE

Scale: 1 inch = 100 feet.

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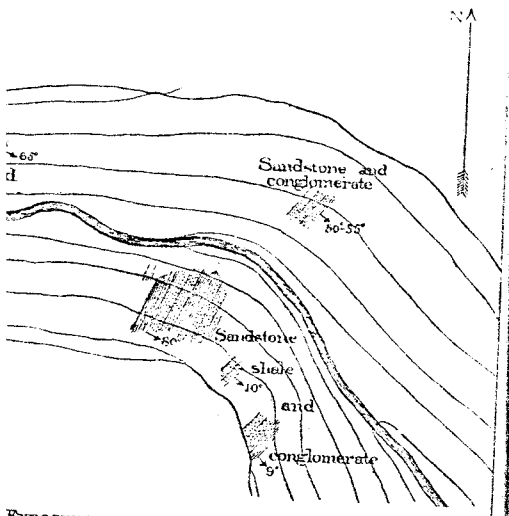
of the sandstone changes rapidly, becoming at first a higher northwesterly one, then a vertical one, and then one to the southeastward or on the other side of verticality; after which it rapidly flattens, so as to be, at the last point examined by us, only 150 steps below the junction, as low as 10° and 9° in a southeasterly direction. Moreover, while the strike of the sandstone at the junction is somewhat near to conformity with that of the Keweenawan beds above, as we pass away from the junction it changes rapidly, so as to be much more to the northward, as indicated on the topographical sketch of Plate X. The exposures on the sides of the ravine in this distance are at times quite large natural ones, and again are so thinly covered with leaves and moss as to be very easily stripped, so that with the definite and conclusive evidence as to dips given by the inclusion of conglomerate beds within the sandstone, there seems no room for doubt that the entire structure is as we have indicated it in figure 2 of Plate X. The whole series of sandstones and included conglomerates and shales here seen is manifestly the same as that already described as showing on the Wall Creek Ravine; and all the statements made with regard to one of these sets of layers will apply equally to the other. The sandstones are white, and nearly purely silicious, or reddened by a slight admixture of clayey material, and the conglomerates hold subangular to rounded pebbles almost wholly of Keweenawan derivation, including the basic as well as the acid eruptives.

The junction, however, while it is here somewhere near the same general horizon of the Eastern Sandstone as on the Wall Creek, is plainly at a very different horizon of the Keweenaw Series. At the junction on Wall Creek there is a belt of conglomerate as much as 135 feet in width, while at the junction here the Keweenawan rock is a diabase, and the first conglomerate belt is a narrow one lying 150 steps to the northwest. Experience gained in mining has shown, as the detailed studies of Pumpelly and Marvine have more conclusively done, that the conglomerate belts of the Keweenaw Series are remarkably persistent, so that the absence here of the broad conglomerate belt met with on Wall Creek is manifestly not due to the thinning out and disappearance of that belt in the short distance of little more than a mile.

That portion of the ravine below the part mapped on our sketch we did not reach, but we have no difficulty from what we saw in accepting M. Agassiz's statement in the paper above quoted that the horizontal sandstone may be traced down-stream for a distance of a mile and a half. He certainly, however, underestimates the distance from the junction to the point at which the flat-lying sandstone may be seen, this distance being not 100 feet but several times as much as this. It is also evident that Mr. Agassiz cannot have seen the very interesting displays of vertically placed sandstone which we have described as showing in the banks and bottom of the ravine for some distance be-



Exposure.

ern Sandstone

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HE KEWEENAW SERIES, ST. LOUIS RAVINE.
100 feet.

low the junction, for had he seen them he could not have failed to notice them in his paper. It is possible that the removal of timber on the summit has somewhat increased the tendency to freshets and has aided excavation and undermining in the ravines and the production of land-slides on the slopes, and that as a result exposures are more abundant than formerly.

DOUGLASS HOUGHTON RAVINE.

The junction of the Eastern Sandstone with the Keweenaw Series occurs in this ravine in Sec. 36, T. 56, R. 33 W., not far from the east line of the section. From here the ravine runs east and southeast through Sec. 31, T. 56, R. 32 W., to the low land about Torch Lake. That portion of the ravine which is of interest in this connection is mapped on Plate XII.

This ravine has attracted the attention of several geologists during the past forty years. The published descriptions of the occurrences here to be met with afford an amusing instance of the very different appearances which the same place may present to different observers. In this case, however, the differences between the several descriptions, while proceeding in part from preconceived notions as to the phenomena which should occur here, have probably not been altogether so derived. The fact is that the occurrences, unless examined in considerable detail, are very confusing. Within a few feet of each other quite contradictory dips and strikes are to be obtained in the sandstone, so that it is not altogether unnatural that discordant views as to the structure here should have been held, the several observers having devoted themselves probably to different points without examining the whole ground. Even the opposite sides of the ravine present sections differing in some important respects from one another. In addition to the difficulties arising from the confused structure of the sandstone are others presented by the decomposed and often shattered condition of the Keweenawan beds and by the steep and slippery sides and wooded character of the ravine.

The following quotations comprise all that we have found with reference to this place:

J. W. Foster, 1848. (Report to Dr. C. T. Jackson, dated Boston, May 26, 1849, Senate documents, Thirty-first Congress, first session, 1849, Vol. III, No. 1, p. 782.) "The southern junction is more clearly defined; but the conglomerate, which is found in such heavy masses on the northern slope, is almost entirely wanting.

"Section 36, township 56, range 33, belonging to the Douglass Houghton Mining Company, affords a good exposure of the rocks. The west fork of Torch river is here precipitated over a cliff of trap 80 feet in height, near the junction, and thence winds along through a deep gorge which it has excavated in the sandstone. The sandstone is of a light yellow color, and contains numerous pebbles, consisting for the most part of white quartz. It dips southerly or away from the trap. On the north side of the stream, it is seen resting on the trap in large blocks, 70 feet above its bed. The sandstone is seen in the banks of this branch of Torch river at short intervals, and contains greenish patches, giving it a somewhat variegated appearance."

FALL OF DOUGLASS HOUGHTON RIVER, KEWEENAW POINT, MICHIGAN.

[From a photograph.]

...This idea seemed to gain corroboration

J. W. Foster and J. D. Whitney. (Report on the Geology and Topography of a portion of the Lake Superior Land District. House documents, Thirty-first Congress, first session, 1850, No. 69, p. 67.) "On one of the affluents of Torch river, (section 36, township 56, range 33,) the junction of the trap is beautifully displayed. The stream is precipitated over a wall of trap 80 feet in height, and thence winds its way through a deep gorge which it has excavated in the sandstone. The conglomerate differs from the lenticular bands described as occurring with the bedded trap, consisting of arenaceous particles loosely aggregated, and containing, near the base, quartzose pebbles. Patches of green and red ochrey clay occur in different parts of the mass, in a concretionary form.

The red and green chlorite rock, fissile, but not stratified, enveloping masses of amygdaloid, is seen on the left bank of the stream, traversed by seams of quartz and calc-spar, underlying to the NW. 50°. Above this the rock is greenstone, presenting a wall-like appearance, and rising in overhanging cliffs."

Alexander Agassiz. (Proceedings Boston Society of Natural History, Vol. XI, pp. 245, 246, 1867. In continuation of paper quoted *ante*, p. 27.) "The same is the case at the Douglass Houghton Creek, in Section 36, Township 56, Range 33, where the creek winds its way through a deep ravine cut out of the sandstone, and at the junction of the sandstone and trap, falls a depth of 172 feet. The chloritic bed is well developed on the south side of the creek, while the north side is more greenstone, and all along the whole length of the ravine up to the falls, a distance of 1½ miles, the horizontal beds of sandstone are readily traced, dipping slightly north near the falls and being horizontal at the opening of the ravine into Torch River valley, plainly showing that they rest unconformably upon the trap range. On examining this sandstone more carefully we find that the strata are made up of alternating layers of sandstone of reddish or yellowish grain, and of beds of loose sandstone containing boulders; some of the beds of boulders resembling what is common on sea-shores as a mixture of mud and shingle. On breaking open several of the small boulders taken *in situ* from the beds we find that they consist mostly of reddish trap, but frequently we come across perfectly well waterworn boulders of grayish trap containing amygdules, identical with the trap of the copper range a short distance west from these beds of sandstone, plainly showing that the sandstone was deposited upon the shores of the ridge of trap forming Keweenaw Point, and has not been uplifted by it as is stated by Foster and Whitney. The case is totally different with the sandstone north of the range that lies conformably upon the trap, but the sandstone of the southern side of the mineral range in the vicinity of Torch Lake is plainly of a different age, lying, as it does, unconformably upon the former. I shall be able, I trust, to make a more careful examination of this subject, and by examining a greater number of points the discrepancy between the observations of Messrs. Foster and Whitney and mine may be explained.

Mr. L. G. Emerson, a mining engineer, who examined these points with me, for a long time resident of Ontonagon County, tells me he has observed a similar state of things at the junction of the trap and the sandstone at Forest Falls and in a southerly direction from Minnesota mine on the south boundary of the range, and that he found there the sandstone beds resting unconformably upon the beds of trap dipping north."

Raphael Pumpelly, 1870–'72. (Geological Survey Michigan, Vol. I, Part II, pp. 2, 3, 1873.) "At the western edge of this belt, its nearly horizontal strata abut against the steep face of a wall formed by the upturned edges of beds of the Cupriferous series of melaphyr and conglomerate, which dip away from the sandstone, at angles of 40° to 60°, according to geographical position. This sharply defined and often nearly vertical plane of contact, having been seen by the earlier geologists at several points along a distance of many miles, and having been found to be often occupied by a thick bed of chloritic fluccan, which was looked upon as the product of faulting motion, was considered as a dislocation.

"This idea seemed to gain corroboration in the fact that, on the western side of

Keweenaw Point, sandstones bearing considerable resemblance to those of the eastern horizontal beds occur, apparently conformably overlying the Cupriferous series. Both sandstones came to be considered as identical in age and as forming the upper member of the group.

"There are many circumstances which make it difficult for us to accept this conclusion. One obstacle lies in the enormous amount of dislocation required, for instance at Portage Lake, where the strata of the Cupriferous series, with an actual thickness of several miles, dip away from the supposed *longitudinal* fault at an angle of about 60°.

"Again, there are at least two patches of sandstone lying on the upturned melaphyr beds near Houghton, though it was not easy to prove that they were not brought thither by glacial action. Mr. Alexander Agassiz informed me that he has found in the horizontal sandstones near this so-called 'fault' abundant pebbles of the melaphyr and conglomerate of the Cupriferous Series, a fact which I found abundantly confirmed on the spot."

M. E. Wadsworth, 1879. (Notes on the Geology of the Iron and Copper Districts of Lake Superior. Bull. Mus. Comp. Zoöl., Whole Series, Vol. VII, No. 1, pp. 115–117.) "It is to be remembered that Mr. Agassiz, in conjunction with Mr. L. G. Emerson, the well-known mining engineer of Hancock, and at one time assistant on Prof. Pumpelly's geological survey, found below the Douglass Houghton Falls pebbles of the melaphyr (amygdaloid) in the sandstone; and from this the conclusion was drawn that the sandstone was younger than the trappean formation. At the time of our visit to this locality, we had no knowledge of Mr. Agassiz's observations, except from the general statement of Prof. Pumpelly. It will be seen that no localities were given by Prof. Pumpelly, although he confirms Mr. Agassiz's statements. The falls were said by Mr. Agassiz to be located at the junction of the sandstone and trap, while on both sides of the ravine the horizontal sandstone beds were traced up to the falls. Our examination showed that immediately below the falls sandstone and conglomerate exist, dipping N. 45° W. 25°. * * * While the majority of pebbles were of the usual character, one grayish granitoid pebble (506) containing epidote was obtained. This has suffered the same *graphic* alteration in its feldspar that No. 527 has. Much of the feldspar is seen to be triclinic. Otherwise than its containing more quartz, its characters are in the main like No. 527. The sandstone, at its junction with the overlying trap, is much indurated and altered, and specimens were obtained showing the junction of the two. * * * As the sandstone underlies the trap, it is of necessity the prior-formed rock. We suppose that this was the locality at which Messrs. Agassiz and Emerson obtained their specimens of melaphyr in the conglomerate. If so, it is easily enough explained, for conformably underlying this sandstone is another sheet of melaphyr, then more sandstone, again more melaphyr, and so on, all conformably underlying one another as much as they do anywhere within the trappean belt, or can do, on account of their origin. Whether this is the spot or not, it is evident from the language of Mr. Agassiz's paper that the gentlemen took their facts and drew their conclusions while they were within the trappean belt, not having found the junction at all, it being some distance below the falls, not at them. From Prof. Pumpelly's statement it would seem that he had made the same mistake, as likewise Mr. Foster had done years before. Something more is necessary to be observed than simply to find a sandstone or conglomerate on the eastern side; it is necessary to prove that it is part of the eastern sandstone, and not a bed intercalated in the trap. The sandstone and melaphyr, a short distance below the dip last given, has a dip of 20°, still inclining to the northwest. The last melaphyr sheet underlies a sandstone dipping at this angle, and is itself underlaid by another sandstone having the same dip. In other words, the last trap on the eastern side of Keweenaw Point is a thin flow of only some 2 feet in thickness, at this locality, and is interbedded between sandstones which immediately above and below it have the same dip that it has. As the river is followed downwards the dip gradually declines

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Geology of the Iron and Copper Districts of
hole Series, Vol. VII, No. 1, pp. 115–117.) "It
onjunction with Mr. L. G. Emerson, the well-
l at one-time assistant on Prof. Pumpelly's
ass Houghton Falls pebbles of the melaphyr
this the conclusion was drawn that the sand-
nation. At the time of our visit to this lo-
ssiz's observations, except from the general
e seen that no localities were given by
Ir. Agassiz's statements. The falls were
action of the sandstone and trap, while on
ndstone beds were traced up to the falls.
below the falls sandstone and conglomer-
While the majority of pebbles were of
peb 506) containing epidote was ob-
alteration in its feldspar that No. 527 has.
Otherwise than its containing more quartz,
The sandstone, at its junction with the
ered, and specimens were obtained show-
as the sandstone underlies the trap, it
e suppose that this was the locality at
d their specimens of melaphyr in the con-
ed, for conformably underlying this sand-
re sandstone, again more melaphyr, and
ier as much as they do anywhere within
their origin. Whether this is the spot
Agassiz's paper that the gentlemen took
le they were within the trappean belt,
ing some distance below the falls, not
it would seem that he had made the
done years before. Something more is
a sandstone or conglomerate on the east-
art of the eastern sandstone, and not a
and melaphyr, a short distance below
g to the northwest. The last melaphyr
gle, and is itself underlaid by another
ds, the last trap on the eastern side of
eet in thickness, at this locality, and is
liately above and below it have the
downwards the dip gradually declines

in steepness, although still dipping northwest. The last dip measured was N. 45° W. 50°. The conglomerate and sandstone below the first basaltic flow, *i. e.* that nearest to Torch Lake, has apparently been acted upon by hot waters. The sandstone has been leached, its feldspathic constituents largely changed into clay, and the pebbles are greatly altered and kaolinized. The constitution of the sandstone and conglomerate appears to have been originally the same as that of the bands interlaminated with the trap, except so far as they are modified by the detritus of the latter. In many places this hot water action has bleached the sandstone and leached out of it all the argillaceous material, leaving it a nearly pure siliceous sandstone. * * * This has also converted some of the finer beds into a fine-grained, highly argillaceous sandstone or arenaceous clay, these beds having probably arrested the progress of much of the argillaceous material. * * * This water action would certainly account for the absence of fossiliferous remains in the sandstone exposed to its effects. Considerable mica in fine scales was seen in the argillaceous bands. Specimens of the various pebbles were taken from the conglomerate. * * * No. 517 is a grayish and reddish-brown granitoid-looking rock, and under the lens is apparently composed of feldspar holding quartz grains. Microscopically it is seen to be a crystalline aggregate of decomposed feldspar and hornblende, holding much secondary quartz. The quartz is arranged in the feldspar in the *graphic* or eozoön form, which makes the decomposed feldspar a most beautiful object in polarized light. The contrast between the brilliantly polarizing quartz and the feebly polarizing, kaolinized feldspar substance is thus strongly brought out. The quartz appears to have been deposited from the decomposed feldspar itself, which breaks up into silica and the kaolin-like material. The quartz contains full fluid cavities, those with bubbles, and vapor cavities. The hornblende is in the usual reddish-brown decomposed masses. Some magnetite was seen. This rock is most probably a decomposed old trachyte, although it would doubtless be regarded as a granite porphyry by most lithologists. No. 515 is a similar but more feldspathic rock. No. 513 is similar to No. 527, and Nos. 514 and 516 are like No. 524. Many pebbles or lenticular masses of clay were seen, that are apparently decomposed pebbles of the conglomerate."

R. D. Irving, 1880. (Manuscript notes.) "In the afternoon of September 6 we examined the ravine on Sec. 31, T. 56, R. 33 W., in company with Mr. L. G. Emerson, of Hancock, with the object of seeing something of the unconformable junction described by Pumpelly as obtaining here between the Eastern Sandstone and the Keweenaw Series. The Douglass Houghton Fall, at the head of the ravine, is over the ordinary diabase-amygdaloid, with the ordinary northwesterly dip that prevails from here all across the Keweenaw Series. Below the fall the trappean beds are badly shattered and decomposed. About 100 paces below the falls, on the south bank, well up towards the top, sandstone layers with included shale and conglomerate were seen dipping to the northwest, or towards the trap, about 50°. The exposure is poor, and largely covered with clay and fallen material from above. Decomposed, ill displayed ledges of trap show within 20 feet of the sandstone. Seventy paces farther down stream, also on the south side, similar layers were seen with a similar dip, and again about 40 steps farther down on the north side of the stream. These ill concealed, northwesterly dipping layers seem to be tumbled and out of position. The pebbles in the conglomerate seem mainly to have been derived from some of the acid members of the Keweenaw Series. Below these inclined layers, for several hundred paces, following the south bank, we saw nothing in the way of satisfactory exposures of the sandstone, which was, however, seen here and there projecting from the bank, or in the stream bed in fallen masses. But at about 300 steps down we found horizontally placed layers of the ordinary white quartzose sandstone, with interstratified conglomerate seams, in which pebbles were found not only of some of the acid, but also of the basic rocks of the Keweenaw Series. Query: Are the dipping layers near to the traps part of the Keweenaw Series or part of the Eastern Sandstone?"

These facts were thought to prove that the copper-bearing rocks formed a sea-shore bluff, along the base of which the sandstone was deposited with its trappean fragments. In order that the reader may understand the condition of things at that point, it will be necessary for us to indicate the structure of the copper-bearing rocks themselves. They consist of a series of old lava flows (diabase and melaphyr), intercalated between beds of conglomerate and sandstone. The traps are known to be lava flows, by the baking and induration of the immediately underlying rock; by the fact that tongues and dikes extend from the overlying trap down into the rock beneath; by the scoriaceous character of the upper portion of the traps, and the coarser crystallization of their lower parts; by the macroscopic and microscopic evidences of flowing, etc. That they in each case were *in situ* before the immediately overlying rock was deposited, is shown by the facts that they have not affected it in any way, and that they present on their upper surface the irregularities and rounded knobs which lava flows are known to have, especially when exposed to water action; by the presence of rounded fragments of the underlying trap inclosed in the overlying conglomerate; by the absence of fragments of the overlying rock in the underlying one, and by the absence of any marks of intrusion of the traps between different beds.

"Sometimes the lava flow was followed by another, without any apparent long exposure of the former; then again the interval between the two succeeding flows was so great, that sandstones and conglomerates having a thickness of from a few inches to half a mile (Marvine), were deposited between them. Of course from this it followed that the surface of the underlying trap suffered denudation, and that afterwards the conglomerate was deposited unconformably upon it. This was the general mode of formation throughout the series on Keweenaw Point. The general condition of things may be correctly indicated by the statement, that in going from the east towards the west the cupriferous series is found to be made up of an increasing number of lava flows and a diminishing number of conglomerates, until a point is reached where the volcanic activity culminated, when the flows diminished and the conglomerates increased, until the Western sandstone was reached. It would follow from the mode of formation, that whenever a sandstone or conglomerate was laid down on the trap, denudation of the latter would take place and fragments of it be inclosed in the unconformably overlying detrital rock; and this would hold good not only of the intercalated beds, but also of the Western Sandstone. All these evidences of denudation would then be merely signs of sequence of time, and not of a difference in geological age. Precisely similar facts may be observed at the present day wherever a lava flow has an opportunity to reach the shore of the sea.

"The question, then, whether the copper-bearing rocks are a formation of a geological age older than the Lake Superior Sandstone is to be ascertained, if at all, on the eastern, and not on the western side. It has just been pointed out on what evidence the Eastern sandstone was said to be younger than the traps; but a careful examination of the region in question showed its incorrectness. At the Douglass Houghton Falls the stream passes over a cliff of trap, and then winds through a gorge having high and very steep banks. It was very natural that, in ascending this stream from Torch Lake to the Falls, the hasty observer should be led to believe that the sandstone and conglomerate extend in an unbroken band up to the cliff at the latter locality, and regard it as an old sea-shore bluff. This would especially be the case should he confine his observations to the stream, and not attempt to explore the clayey, slippery, difficult sides of the ravine. The writings of previous observers give no evidence that they did more than to follow the bed of the stream; and they all concurred in stating that the sandstone was horizontal, or nearly so, up to the Falls, at which place the trap was said to be first met. When Dr. Wadsworth examined the locality in 1879, he not only explored the bed of the stream, but also the bluffs on both sides. These examinations showed that the sandstone and conglomerate were not horizontal, but that they had a gradually increasing dip as the Falls were approached from 5° up to 25°, while on both sides of the stream the traps were

U. S. GEOLOGICAL SURVEY

BULLETIN NO. 23 PL. XII

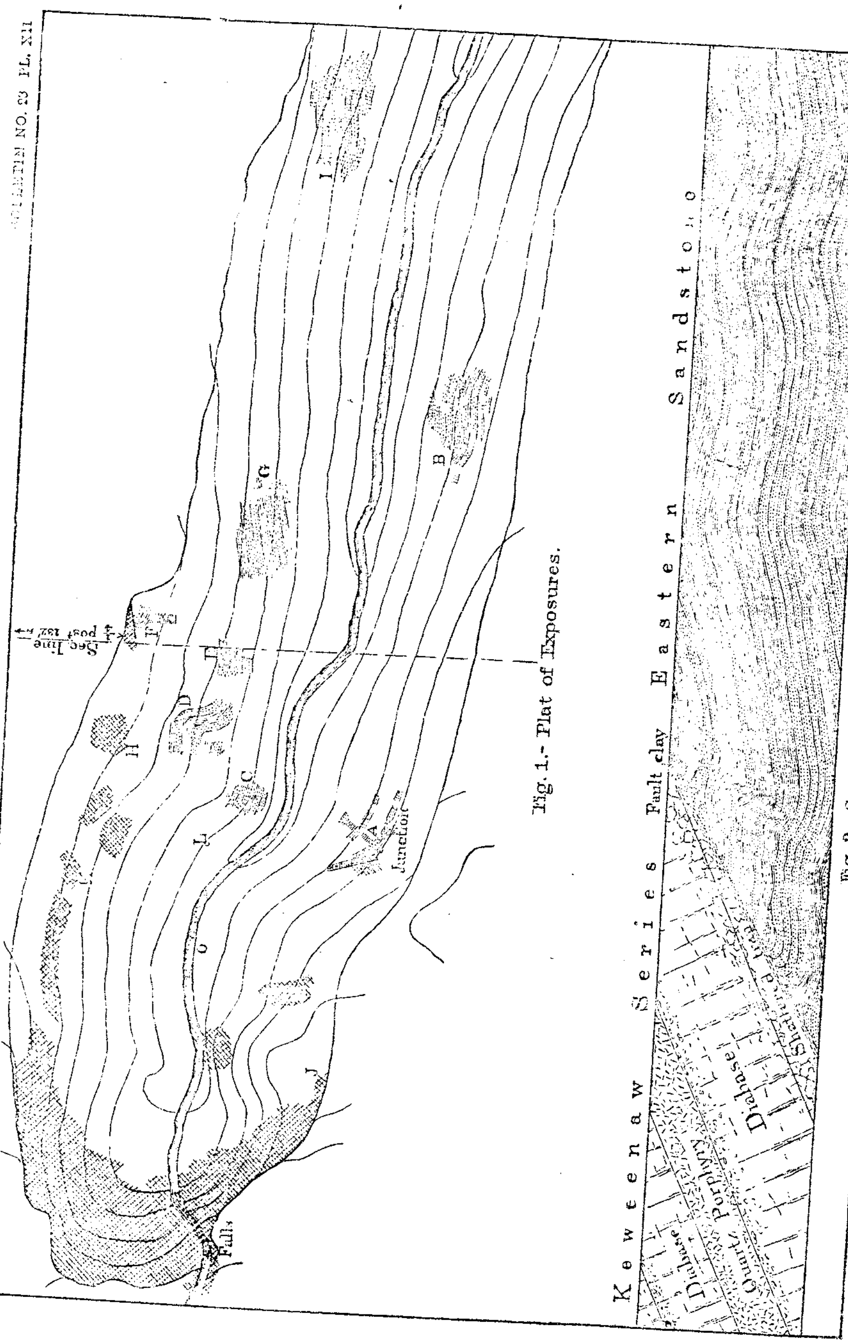

Fig. 1.- Plat of Exposures.

Fig. 2.- Generalized Section showing Structure.

JUNCTION OF THE EASTERN SANDSTONE AND THE KEWEENAW SERIES, DOUGLASS HOUGHTON RAVINE.

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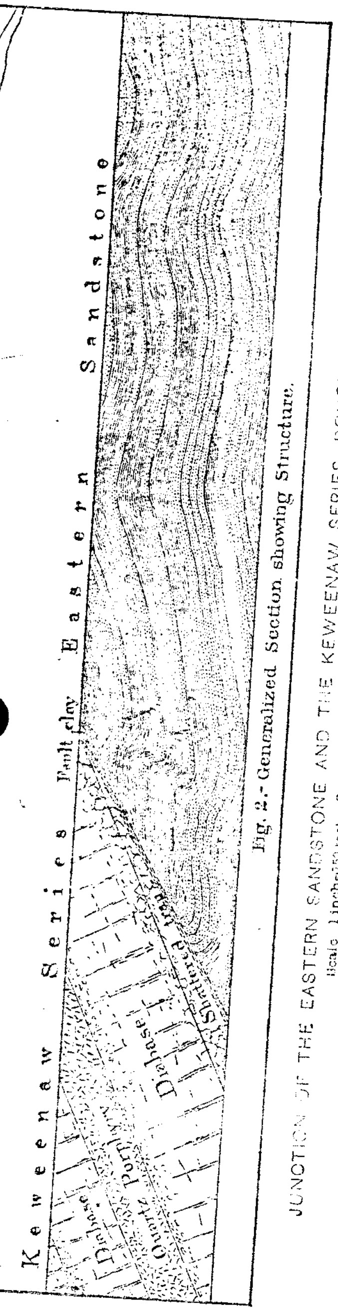

Fig. 2.- Generalized Section showing Structure.

JUNCTION OF THE EASTERN SANDSTONE AND THE KEWEENAW SERIES, DOUGLASS HOUGHTON RAVINE

found holding the same relations to the sandstone and conglomerate that they have been stated to hold elsewhere in the series. These traps had been masked and concealed by the falling rock and earth; but, on digging, foot after foot of the junctions of a number of the lava flows and their adjacent sandstones were exposed. The flow nearest Torch Lake is about two feet in thickness, lying between two beds of sandstone, all having a dip of 20°. Junctions of these beds and the flow were exposed by excavating along a distance of about twenty feet. The trappean pebbles seen by former observers at the Falls were seen to have been derived from the underlying trap, as they are throughout the entire series, and not from the supposed old sea-shore bluff. In the same way, the sandstone and conglomerate were carefully followed up by the Hungarian River from Torch Lake, and the same condition of things observed.

"These observations are of a kind to exclude any probability of a mistake; they are clear and definite. Moreover, they explain the errors of previous observers, and until refuted, if they can be, they conclusively show that the Eastern Sandstone and the copper bearing series are one and the same geological formation, although differing in time sequence. It is a remarkable circumstance, that, while this evidence is so clear and explicit, the more recent writers have carefully avoided any mention of it, but have endeavored to discuss the subject on theoretical grounds chiefly."

(Ibid., p. 563.) "Since the first part of this work was put in type, another report on the geology of Keweenaw Point has been published by Professor Irving, in the Third Annual Report of the Director of the United States Geological Survey. The state of our knowledge up to the time of the casting of that portion of the work has been presented. * * * In Irving's report the before-mentioned observations * * * of Wadsworth at the Douglass Houghton Falls are accepted and pronounced correct in every particular but one. Irving then acknowledges that the copper-bearing rocks are continuous with the Eastern Sandstone below the falls; but in order to escape the dilemma in which this places him, he says that below on the stream is a covered space between the true Eastern Sandstones and those which every previous observer had called such, and that here is the junction between the sandstone and Keweenawan Series. This space he said Wadsworth had bridged over in his imagination. To this the latter replied, 'that, by digging in the stream and on the banks of the ravine, he had actually traced (not imagined) the relations of these rocks, going from those dipping 5 degrees up to those dipping 25 degrees, and that they were seen to form a continuous super-imposed series, no such cliff as imagined [by Irving] existing between them.'"

Following the Douglass Houghton ravine upwards from the lowlands about Torch Lake we found the sandstone, of the usual quartzose type, projecting frequently from the sides of the ravine in larger or smaller exposures, which, for a long distance from the mouth of the ravine, show an essential horizontality of the layers. Subordinate to this horizontality, however, is a gentle bowing or curving structure, by which the dip is often from 2° to 5° in different directions. Thus dips of this amount were measured in northwest, southwest, and southeast directions. As the ravine is ascended, the exposures show more interstratified, soft, shaly matter, which becomes conglomeratic with well-rolled pebbles of the various Keweenawan eruptives, chiefly of the acid type, but by no means to the exclusion of the basic kinds. The sandstone layers interstratified with these red shaly conglomerates vary from white to reddish-white in color, according as they are more purely quartzose or contain an admixture of the red clayey material which is the main constituent of other layers. This sandstone is commonly quite friable

and loose, but again is often very considerably indurated locally. The induration, as is suggested even by the appearance to the naked eye and as is demonstrated by the thin section, is a quartzose one, the infiltrated quartz having built out the fragments into interlocking areas. The first point in ascending the stream at which we noticed the interstratifications of sandstone and red shaly conglomerate is about 450 steps below the junction of the Eastern Sandstone and Keweenaw traps, as subsequently described. Below this we traversed a considerable interval without good exposure. At this point a white layer of sandstone overlies 20 feet or more of the shaly conglomerate on the south bank of the ravine. It is evidently the place noted by Mr. Chauvenet in the quotation above given.

From here up-stream for 300 or more paces, or to within 150 steps of the junction with the trap, we found the essentially horizontal position of the sandstone and interstratifications with shale and shaly conglomerates continuing. After this, however, more marked disturbances in the sandstone begin to display themselves. At about 100 steps below the junction, on the north bank (point G of the topographical sketch of Plate XII), a large face of the conglomerate and shale shows, having been laid bare by a slide not many years old. The exposure here is 28 steps in length along the face of the bank and shows layers in all about 100 feet or more in thickness. Here the shaly conglomerate is in large proportion compared with the sandstone, which appears in a few comparatively thin layers. The inclination is as much as 25° to 30° to the northwest, while only a short distance down stream on the other side of the ravine the layers are essentially horizontal (B of Plate XII).

Continuing now along the north bank of the ravine we come, within a few steps, to a succession of slides, evidently of very recent date, between which there remain spaces still covered with trees and bushes. The first of these slides reaches nearly to the top of the ravine. Here, immediately below the top of the bank (F of Plate XII), we found the conditions represented in Figure 4. Just below the top of the bank

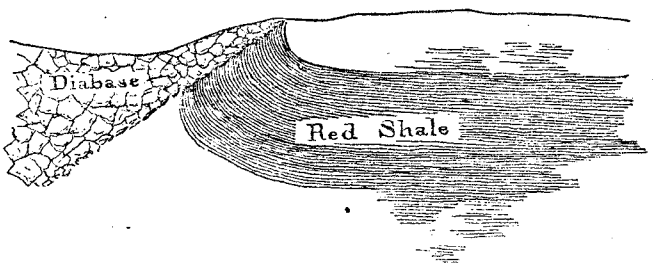

FIG. 4.—Junction of a member of the Eastern Sandstone and Keweenawan diabase, Douglass Houghton Ravine, Keweenaw Point, Michigan.

there remains here a portion of the trap or diabase, immediately beneath and in immediate contact with which are red, for the most part non-conglomeratic, shales, the layers of which present edges having an

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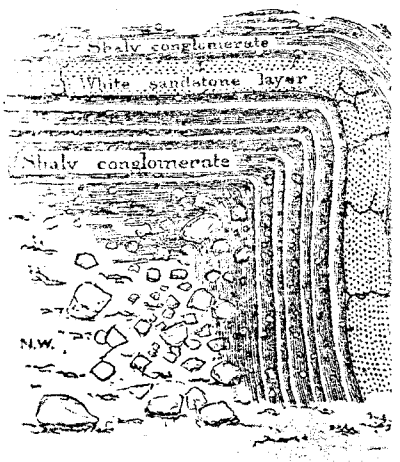

FIG. 5.—Bend in the Eastern Sandstone, nort
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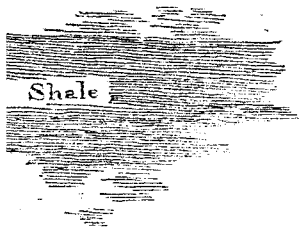

ne and Keweenawan diabase, Douglass Hough-
Point, Michigan.

rap or diabase, immediately be-
which are red, for the most part
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upward curvature from a horizontal position as they approach the contact with the trap. Extending downward from this junction for about 50 feet, we dug a trench with a view to determining more definitely the position and composition of these layers than we could do from the mere surface exposure. We found them for the length of the trench to hold but few pebbles and but one interstratified sandstone layer. The inclination within the trench we found to be 12° slightly to the east of north, or into the bank. Farther down this slide sandstone projects in the usual massive layers, interstratified with shale and conglomerate, but so badly covered with the débris from above that we could not determine satisfactorily the position. A short distance to the west and somewhat farther down the bank, however, on the other side of a tree-covered projection, we found these same layers better exposed and inclining slightly to the northwest (E of Plate XII).

A few steps farther to the west, following these inclining layers, we found the very interesting exposure marked D on Plate XII. The layers of this exposure are not visibly continuous with those of the preceding one, there being a few feet intervening where the rock is concealed; but that they are exactly the same layers is manifest from their entire similarity in character and interstratification. The position of the layers here is represented in Figure 5, which is sketched from a

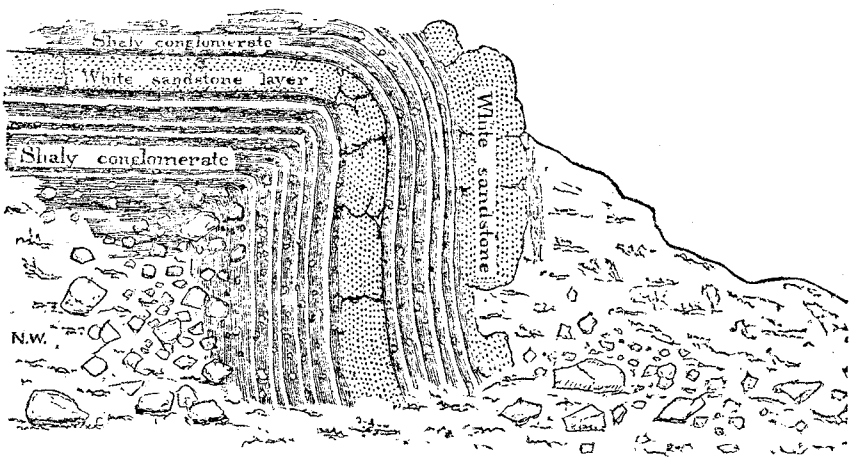

FIG. 5.—Bend in the Eastern Sandstone, north side of Douglass Houghton ravine, Keweenaw Point, Michigan. Scale, 20 feet to the inch.

photograph taken by us. The entire thickness of the layers visibly affected by this singular bend is as much as 30 or 40 feet. Vertically above this exposure, but separated from it by a considerable space covered with trees and fallen material, in which we vainly dug to find a junction, large masses of trappean material show up to the top of the ravine (H of Plate XII). This trap is continuous with the remainder of the Keweenawan exposures up to the falls and beyond. From the